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CANADA’S TRADE FLOWS OF ELECTRONIC WASTE: MAPS AND TRENDS

BAHRAM VAKILIAN

DÉPARTEMENT DE MATHÉMATIQUES ET DE GÉNIE INDUSTRIEL

ÉCOLE POLYTECHNIQUE DE MONTRÉAL

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M. MARGNI Manuele, Doctorat, président

Mme BERNARD Sophie, Ph. D., membre et directeur de recherche

M. WARIN Thierry, Ph. D., membre et codirecteur de recherche

M. JOANIS Marcelin, Ph. D., membre

DEDICATION

This thesis is dedicated to my parents

for their love, endless support

and encouragement.

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RÉSUMÉ

Avec les avancées technologiques et l'utilisation généralisée des dispositifs électroniques, le sujet des rebuts électroniques comme l'une des sources de déchets avec la croissance la plus rapide au monde, particulièrement en Amérique du Nord, a été largement souligné dans les cercles politiques et académiques.

L'étude porte sur ce sujet dans un contexte canadien et pose l'hypothèse selon laquelle il est largement admis que les pays développés exportent leurs rebuts électroniques vers les pays en développement; le Canada serait donc un exportateur de déchets électroniques vers ces pays.

Afin de répondre à la question de recherche et soutenir l'hypothèse, l'étude cartographie le réseau Canadien du commerce des déchets électroniques au moyen du code de base de données de l'ONU Comtrade 854810 comme données de substitution pour les années 2013 et 1996 et identifie la tendance au cours de ces périodes. Les partenaires commerciaux, les destinations, avec leur ampleur et leurs directions au cours des différentes années sont également démontrés. En poursuivant l'analyse grâce à l'utilisation de modèles de séries chronologiques, cette étude projette les flux commerciaux pour les années 2014 à 2018.

En outre, cette recherche a évalué les facteurs d'échanges internationaux, y compris les réglementations nationales et internationales, les raisons de ces opérations ainsi que les avantages et les contraintes potentielles.

En conclusion l'étude démontre que l'hypothèse est rejetée; l'analyse des données de substitutions montre que le flux de déchets électroniques du Canada, bien qu'il soit censé être axé vers l'exportation, a été ces dernières années dirigé vers l'importation. Au cours de la dernière décennie, le pays est passé d'exportateur à importateur net de déchets électroniques.

Les projections pour les années 2014 à 2018 démontrent que les importations et les exportations devraient continuer de croître sensiblement au même rythme et qu'à la fin de cette période, la position du Canada sera semblable à celle de l'année 2013 en tant qu'importateur net de déchets électroniques avec trois fois plus d'importation que d''exportation.

ABSTRACT

By the expansion of technology advancement and the pandemic use of electronic devices among various communities, the topic of electronic waste as one of the most rapidly growing source of waste in different parts of the earth, especially in the North American region has been vastly pointed out in the political and academic circles.

This study focuses on this issue at the Canadian scale in order to answer the hypothesis that it is widely accepted that developed countries export their electronic waste to developing countries; therefore Canada is an exporter of electronic waste to developing countries.

In order to answer the research question and its hypothesis, this study, by means of UN Comtrade database code 854810 as the proxy data, mapped the Canadian e-waste trade network for 2013 and 1996, and identified its trends during these periods. The trade partners and destinations as well as their magnitude and directions in different years have also been shown. By continuing the analysis via the use of time series models, this study has forecasted the short term future of these trade flows from 2014 to 2018.

Furthermore, this research evaluated the international trade factors, including domestic and international regulations, along with the reasons of such trades as well as the benefits and potential limitations.

In conclusion, this research analysis rejected the hypothesis; the analysis on the UN Comtrade database code 854810 shows that the proxies e-waste flow for Canada, despite the fact that it is expected to be more toward export, has been in recent years on the import. In the last decade, the country from a net exporter switched to the net importer of electronic wastes.

The forecasts outcome also shows that the Canadian import and export from 2014 to 2018 are expected to continue rising with almost the same speed, and that by the end of this period, Canada will still stay similar to the latest stage in 2013 as a net importer of the electronic waste with three times more import than export.

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LIST OF ABBREVIATIONS AND NOTATIONS

ACES	Atlantic Canada Electronics Stewardship
ARMA	Alberta Recycling Management Authority
BAN	Basel Actin Network
BC	British Columbia
BOL	Bill of Lading
CCME	Canadian Council for Ministers of Environment
CEA	Consumer Electronics Association
CFL	Compact Fluorescent Light
CPI	Consumer Price Index
CRT	Cathode Ray Tube
CWTA	Canadian Wireless Telecommunications Association
EC	European Commission
EEE	Electronic and Electrical Equipment
EFC	Electro-Federation Canada
EHFs	Environmental Handling Fees
EMA	Environmental Management Act
EPA	Environmental Protection Agency

EPEA	Environmental Protection and Enhancement Act
EPEAT	Electronic Product Environmental Assessment Tool
EPI	Environmental Performance Index
EPR	Extended Producer Responsibility
EPRA	Electronic Products Recycling Association
EPS	Electronic Product Stewardship
EPSC	Electronic Product Stewardship Canada
EQA	Environment Quality Act
ESABC	Electronic Stewardship Association of British Columbia
EU	European Union
GDP	Gross Domestic Product
HS	Harmonised System
HTB	Home Theater in a Box
ITAC	Information Technology Association of Canada
MAD	Mean Absolute Deviation
MAPE	Mean Absolute Percentage Error
MSD	Mean Squared Deviation
OECD	Organization for Economic Cooperation and Development
OES	Ontario Electronic Stewardship

PSPs	Provincial Electronic Product Stewardship Programs
PWGSC	Public Works and Government Services Canada
RCC	Retail Council of Canada
RCRA	Resource Conservation and Recovery Act
RCMP	Royal Canadian Mounted Police
RECYC	Société Québécoise de Récupération et de Recyclage
RoHS	Restriction of Hazardous Substances
SVTC	Silicon Valley Toxics Coalition
SWEEP	Saskatchewan Waste Electronic Equipment Program
UN	United Nations
WEEE	Waste of Electrical and Electronic Equipment
WDA	Waste Diversion Act
WDO	Waste Diversion Ontario
WRAP	Waste Reduction and Prevention

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CHAPTER 1 INTRODUCTION

1.1 Importance of the Study

Canada's environment is effected by electronic waste (E-Waste) and the influence of the defined regulations for its disposal and the export from the country. Based on information from Environment Canada, more than 140,000 metric tonnes of electronic equipment are aggregated in Canadian landfills annually [1, 2], which consist of various electronic products, from phones, televisions, computer equipment, and batteries to small electronic home appliances. It is anticipated that the same size of this landfill's wastes are exported annually to developing countries recycling operations, due to less expensive labor and recycling processes which is approximately 10 times cheaper than through domestic disposal [3].

Although no such database that shows the e-waste trade flow of the countries through their export and import capacities and their trade partners on a global basis is in existence, Canada is therefore not an exception. Despite this limitation, this research analysis by use of proxy data will show that the e-waste flow for Canada, although expected in the other past literatures, has changed dramatically toward new destinations with lots of trade flow gaps.

Therefore, it is by tracking these trade flows as well as their capacity to each final destination that the economy would profit; this would be done by identifying the illegal trade flows and potential gaps in the current regulations for decreasing illegal trades and domestic disposal. Also, introducing a time series model for forecasting this growth potential based on the available statistics from preceding years with the involved influential trade flow factors could help the government to provide a better recycling infrastructure for confronting this environmental issue in the coming years.

1.2 Research Objectives

The aim of this thesis is to identify the e-waste trade flows of Canada along with its partners, destinations as well as its past, present and future trends. In this way, there are three major objectives defined that have been followed throughout this thesis:

- Evaluation of the international trade factors, including domestic and international regulations along with reasons of such trades as well as benefits and potential gaps.
- Mapping Canada's e-waste trade network and characterizing the trade destinations and partners.
- With conditions imposed on data, developing a time series model for forecasting the future growth trend potential of Canada's e-waste.

1.3 Research Questions and Hypothesis

In order to achieve the research objectives, this study will answer the following question and hypothesis:

- Have there been changes to Canada's e-waste trade flow in past years and in which direction?

Hypothesis: It is widely accepted that developed countries export their electronic waste to developing countries; Canada is an exporter of electronic waste to developing countries.

To answer the above question and hypothesis, the following detailed narrowed down questions need to be answered first:

- How should this flow be measured?
- Which factors influence this trade flow the most?
- What is the short-term future picture of e-waste flow in Canada?

The detailed methodologies adopted for finding the answers for the above questions have been explained in chapters four and five.

1.4 Thesis Chronology

This study is structured in five chapters, starting with the explanation of the importance of this study and its objectives along with its milestones of the achievements and the research questions in the initial section.

In the second part, the issue of e-waste is discussed as a general term, including its definition, variations and identified trade flows, together with its prospect of regulation in the international format. Furthermore, in this section also, the situation of WEEE in Canada along with its challenges, current recycling capacities and the responsible organizations will be evaluated.

In the third chapter, the e-waste legislation and the regulations at the state and the provincial levels are discussed. Furthermore, a detailed view of each provincial regulation, as well as their comparison with each other and with other countries including the European Union and the United States is analyzed.

Chapter four will be the core of the database and the methodology used in this study as well as its analysis for identifying and mapping the e-waste trade network of Canada along with its main trade partners. Furthermore, this chapter will look at the identified gaps, their analysis and illegal flows discoveries.

In the fifth and final chapter, the future trend of e-waste in Canada, conducted with the use of two time series models, are analyzed and the short forecast results for five years has been offered for both the import and the export. In this section, recommendations are also provided for the e-waste database issue as well as its potential ways for creation in addition to a few identified solutions discussed for confronting the issue of e-waste at the national level.

The final point of this thesis is a summary of the total findings and the conclusion along with a few recommendations for the future studies in this topic.

CHAPTER 2 LITERATURE REVIEW

2.1 E-waste General Prospect

The debate between developed and developing countries as well as their current and future roles on the world's global flow map of e-waste has drawn great interest in the political, economic, and academic realms. By expanding the use of electronic items in 21st century, the topic of Electronic Wastes as one of the hazardous items that negatively affects the environment has been vastly used and discussed in recent years [4]. Despite this cumulative interest, to the best of the author's knowledge, there have been limited studies done on the trade flow of e-waste in Canada with concentration on the current country's legislations and import and export trade partners.

Presently, Waste of Electrical and Electronic Equipment (WEEE) is a term which refers to about 900 electronic products in 58 different categories worldwide [5]. This type of waste, which represents about 5% of the total solid waste, is growing faster annually than any other source of municipal waste on the planet [6]. In the United States alone, this expansion is estimated to be 8.6% annually, which is one of the highest expansion rates among developed countries. This is assuming that American municipal waste increases by only 1.2% per year [7]. Luckily, this expansion is slightly lower in Canada since it is estimated to be 4% annually [8]. In this way, the latest statistics for e-waste generated in Canada in 2012, shows a volume of 24.72 kg per inhabitant and 860.74 metric kilotonnes for the entire nation [9].

On the other hand, in 2006 the United Nations (UN) estimated that 20 to 50 million tonnes of e-waste were produced annually worldwide [10]. In 2010, the UN then made the estimation was predicted that there would be a production of 40 to 70 million tonnes by 2015, mainly due to expansion of the role of electronic products in any community lifestyle [11]. In this way, Canada is not an exception and is influenced annually by this expansion.

2.2 Government of Canada's E-waste Definition

WEEE category has been defined differently among countries. In Canada, the government defines e-waste as the "…*surplus electronic and electrical equipment that is not suitable for reuse*…" [12].

Based on this definition, any electronics that are no longer reusable fall under the e-waste category. This has slightly become controversial recently due to the fact that the e-waste definition varies among different countries as the time period of using electronic devices has decreased by users due to technological improvements rather than technical problems. Therefore, it is common to see people dispose electronic devices such as mobile phones and laptops, even though they are still usable. These devices have to be considered as e-waste, but because this is not the case, these devices end up in developing countries as second hand electronic devices for reuse purposes.

Furthermore, the government of Canada defines electronic and electrical equipment as "*…any equipment with a plug, battery or that uses electricity to perform its intended function excluding vehicles and vehicle parts…*" [12].

2.3 Canada's Recycling Capacity

By looking through the annual export data, the limited capacity recycling sites compared to the produced e-waste amount per year in Canada can be more obvious. In the province of Ontario, which is the most populated province in Canada, 9.1% out of 14,586,000 household electronic used appliances had been collected for the purpose of reuse or recycling, which consists of information technology and telecommunications equipment's in 2004; the rest been discarded [13].

On the other hand from an organizational and non-residential perspective, findings from a survey by the Ontario Electronic Stewardship (OES) in 2011 shows that if this province is used as a benchmark for the country's e-waste problem, two-thirds of businesses do not even have any end of life plan for their electronic products due to the fact that their use of electronic products is expanding each year. The fact that the technology lifecycle changes for these businesses must be taken into account as well because their lifecycles within many organizations is currently between 18 to 36 months due to the constant upgrades, which serves as another direct contributing factor to the production of e-wastes [14]. By considering this fact, it seems reasonable then to accept the estimate that generally about 50 to 80 % of all end life electronic products are exported annually from North American countries to developing countries in Asia and elsewhere instead of being recycled domestically [15].

On the other hand and more specifically on just the mobile phone market, the research by recycle my cell program of Canadian Wireless Telecommunications Association (CWTA) shows, despite this fact that 96% of the all materials used in cell phones are recyclable, only 12% of the country's cell phones has been recycled [16, 17].

Generally speaking, it is estimated that in Canada itself, out of all produced e-wastes during a given year, only 10% are recycled or refurbished whereas the remaining 90% are disposed into the country's landfills [8]. One of the main reasons for this low recycling rate and high disposal rate in landfills which is based on the Electronic Product Stewardship (EPS) in Canada, is the cost of recycling electronic products in the country. This is estimated to be four times more than the use of a landfilling disposal [18]. Therefore, by expanding on this procedure, the risk of the waste percolating into the soil and the water resources as well as negatively influencing nature are heightened and the need for new recycling sites for the long term are essential.

2.4 Regulations

By the start of the 21st century, Canada like most industrial nations, followed the global trend and has ratified several programs and policies for controlling and monitoring electronic products as well as their end of life cycle in the hopes of transferring the responsibility and financial weight of e-waste disposal and recycling from the users to the producers. In this way, initiatives such as the Electronic Product Stewardship (EPS) program are of paramount importance among effective programs which are intended to extend producers responsibility (EPR) at both the provincial and federal levels. Although the program design changes in different provinces, it generally forces electronic producers to improve the eco-friendliness of their products by eliminating the use of toxic materials such as toxic chemicals in the product [9, 19]. Currently, this program is in effect in nine provinces, including British Columbia, Nova Scotia, Prince Edward Island, Ontario, Saskatchewan, Manitoba, Quebec, Newfoundland and Labrador and Alberta [20].

From a historical perspective, more than half of the Canadian provinces designed their own legislations between 2003 and 2010 for disposable e-wastes [21]. Therefore, due to the fact that Canada's e-waste legislations are mainly provincial, the comparison of similar legislations from other parts of the world such as those found in the U.S can be useful in showing significant differences. As an example, in the U.S. one of the traditional systems used for managing the e-waste costs is general tax base funding. In this model, a fixed amount of tax is imposed on all taxpayers for funding the e-waste costs to the entire society [22]. Although this e-waste cost management system does not specify the targeted electronic consumers and producers, it was used in past years among different states and it has only been in recent years that the system has started to change. This shows the recent creativity of this e-waste regulation topic among developed countries especially in the North American region after the expansion of electronic production and consumption. In chapter three, these issues along with the detailed comparison of the Canadian provincial legislations will be evaluated.

2.5 Electronic Product Stewardship Canada

The Electronic Product Stewardship (EPS) is a Canadian non-profit organization established in 2003 from a collaboration effort from the Electro-Federation Canada (EFC) and the Information Technology Association of Canada (ITAC), two fundamental Canadian associations in electronics and technology. The main intent of this establishment was to prepare a platform to serve both governmental and industrial organizations in order to promote, design and implement sustainable effective and efficient solutions for the electronic waste problem in the country. According to claims from the organization, since 2004 more than 380,000 tonnes of e-waste products have been diverted from entering landfills by various recycling programs in throughout many provinces including British Columbia, Alberta, Saskatchewan, Manitoba, Ontario, Quebec, Nova Scotia, PEI, and Newfoundland. Examples of such electronic products include mobile phones, computers, printers, televisions and audio/video devices [18, 20].

The Canadian sections of the leading electronic corporations are the main members of this organization. More than 30 well-known corporations are involved such as IBM, Apple, Dell, Toshiba, Sony, Lenovo, Panasonic, Samsung, Hewlett-Packard (HP), Cisco Systems Inc. and Canon are the main board members, and the associate members consist of Asus, LG Electronics Inc., Microsoft, BenQ America Corp., Ciaratech, NetApp Inc., Northern Micro Inc., EMC Corporation, Epson Cisco Systems Inc., MMD-Philips, Fujitsu Canada Inc., Xerox Canada Ltd., Lexmark Canada Inc., Oracle Inc. and Brother International Corporation (Canada) Ltd. [20].

Since 2006, the organization publishes an annual report for further investigation on an environmentally friendly design of the electronic products each year. The report aims to examine technology developments and changes in different manufacturers and their impact on the recycling and closing loop systems progresses. The report also investigates the hazardous and non-hazardous materials contained in different electronic products and their reuse or recovery yearly change of the technology [20].

In the 2013 report, EPSC claims that the amount collected per capita since the program's launch was 5.1kg on average, in which, Ontario had the highest amount collected per capita [18].

2.6 Global Trade Flows and the Waste Haven Hypothesis

Through the expansion of industrialization, developed countries have seen greater incentives in recent years to export e-waste to Asia and the other developing countries [23]. The driving factors for these incentives are due to regulatory stringencies and shifting pollution from these industrialized countries to the developing ones, which is widely known as the pollution haven effect [24].

As based on this hypothesis and looking at the international waste haven effects in detail, the waste trade flow leans toward countries with a lower environmental regulation. In other words, the increase in waste imports is directly linked to deterioration in environmental regulations. In general, it is expected that for every percent drop in the environmental regulations in one of the bilateral waste trade partners, the import of the wastes from the other foreign trade partner increases by 0.32%. This issue can be more understandable when taking into consideration that developed countries in average gain from a 39% higher environmental regulation index than the average developing nation's environmental regulation index [25].

These effects can be even more sensible when combined by the other waste trading facts. The pollution haven effect is also suggesting that by rising the per capita income in a country, the willingness for accepting the foreign hazardous waste in a country decreases [26]. As it is not hard to imagine that in most cases, the so called developed nations are gaining from the higher per capita income and GDP, which makes it easier to guess why a waste trade flow goes towards developing countries rather than developed ones.

On the other hand, it is widely assumed in most of these trading cases, the majority go against international treaties such as the transboundary movement of hazardous waste in the Basel convention which restricts countries for implementing illegal exports other countries [27], and EC legislation (the Waste Shipment Regulation) [28].

As an example, a 2005 study by Greenpeace International in Europe shows that out of 18 European seaports that have been inspected by this organization, 47% of these exported wastes, including e-waste, that were being shipped to various places in the world were taking place illegally [29].

By considering the forecasts for the future prospect of e-waste production, this illegal trade flow can be even further expanded. It is expected that over the next 20 years, a western European household would produce an estimated 900 kg of e-waste, which is the equivalent of about 46 kg per year [30].

On the other hand, it is estimated that in the European Union that around 60% to 75% of all the medium and large-sized appliances are not collected properly annually for recycling purposes; rather, they would be involved in the so called hidden flows, in which a portion ends up being exported into developing Asian and African nations. A possible reason behind this phenomenon, as mentioned before for the other parts of the world and among the industrialized countries, is based on the labor cost; recycling a computer in a country like Sweden would cost about €10 whereas in countries such as India, the same recycling cost would be only €1.5 [28].

In the North American region, most of the flow goes toward Asian countries, the most significant being China. The observations from the Silicon Valley Toxics Coalition (SVTC) in the U.S. and the Basel Action Network (BAN), both of which are non-governmental organizations, showed and predicted that almost 80% of e-wastes in the United States which were collected for the domestic recycling have been exported to the informal recycling sites in developing countries [31]. Although this number compared to the landfills disposal in the country is relatively low, it shows that a great export volume into the other developing countries exists.

Studies from the U.S. Environmental Protection Agency (EPA) from 2003 to 2005 show that about 80 to 85% of the e-waste generated during this period in the United States have been discarded into landfills; therefore, all these exports is the 80% of the 15% to 20% of the remaining e-waste. The volume of the landfills disposal in 2005 is estimated to be more than 1.36 million metric tonnes [32].

The Asian sector is the major destination of the global e-waste and is therefore an important recycling port. China has a major role in the WEEE trade flow map of Asia, as it is the main importer of the e-waste and, at the same time, is the largest exporter of the electronic equipment's [33]. The second rank in the region is India which is also the second most populated area in the world. In Delhi, which is the second largest city in India, more than 10,000 to 20,000 tonnes of e-waste has been recorded annually, in which there are more than 25,000 workers are employed on the scrap yards [29].

In Canada this trade is expected to be more toward Asian countries, mainly China. A study by the Basel Actin Network (BAN) team in 2002 shows a large amount of e-waste labeled by different Canadian institutions such as Air Canada, destined from Vancouver, British Columbia to Guiyu, a city in the Guangdong province of China. This shipment consists of e-waste products such as printers and computers, which are the sort of hazardous e-waste products that are banned from being exported under the Basel convention. Canada, as a full member, is expected to refrain from getting involved in these illegal shipments because of its agreement to the convention. BAN estimated that about 20,000 tonnes of e-waste from these kinds of exports has come from just the computer waste sector into the Asian region in 2002 [15].

Also according to a report given by the RCMP, there has been over 500,000 kg of e-waste that has been shipped solely from the port of Vancouver towards developing countries from 2005 onwards [34].

Based on the mentioned reports, it can be expected that with respect to future prospects, this trend of e-waste trade flow will continue or even grow. This study did not find any evidence based on the literature review conducted for Canada or any other developed countries that show information to the contrary. It is widely accepted that waste and e-waste are moving from the developed to the less developing countries.

There are different factors that can explain this issue. A difference between treatment and disposal costs among developed and developing countries can account for part of the reason; however, the fact that it can be due to less restrictive environmental regulations between southern and northern countries that may cause this issue. A study by Bernard [35], on the second-hand markets shows, strict laws and regulations found in the North that induce Northern firms so that product reusability is reduced. As a result, the flow of non-reusable waste towards the southern regions increases, resulting in a magnification of the pollution haven effect [35].

By analyzing past data and the literature reviewed, it can be seen that Canada, like any other developed country, is expected to be part of the e-waste trade flow to developing countries. The difference for Canada however is that these trades were not traced back to the nation and the driven factors were not analyzed in depth as much as other countries. This is keeping in mind that the amount of e-waste has increased from 2002 as the amount of electronic products has increased in the country. In 2011 alone, Canadians invested more than $11.5 billion in electronic devices, excluding the amounts spent on cellphones and video games [36]. In a tangible technology example of the new generation of electronic products in the country, it was estimated that more than 500,000 tablets were imported in 2010 and that this amount increased threefold to 1,500,000 the year after [37]. There is no doubt that this huge amount of tablets is going to become e-waste in the following years.

Generally speaking, the e-waste issue that the world will face in the future will constantly grow annually, which is evident by way of the many examples that can be illustrated. Based on the Consumer Electronics Association (CEA), the total market revenue of the global electronic products in 2014 is estimated to be around $208 billion. With such revenue, is not unexpected to see producers produce more electronic products and consumers desire to consume more [38]. Therefore by the coming years is not unexpected to see the topic of e-waste is getting more highlighted into the world news headlines.

2.7 Basel Convention

From an historical perspective, the Basel convention is most renowned for its progress in controlling the transboundary movements of hazardous wastes under the mandate of protecting human health as well as the environment from their adverse effects. The first convention took place on the 22nd of March 1989 in Basel, Switzerland, with its actions officially being taken into effect on the 5th of May 1992 [39]. In 1995, the Ban Amendment was adopted to the Convention, prohibiting the export of any hazardous waste from the nations as shown in Annex VII to those nations that are not listed in this section; this basically comprises of all OECD and European Union countries, including Liechtenstein. From this point forward, this relation will be noted as being among A7 and non-A7 countries [40].

From the initial steps, Canada was one of the first countries who signed the convention on 22nd of March 1989 and ratified it on 28 August 1992. This is not the case for the other important member of the North American region, the United States which signed the contract but did not ratify it [41].

As per the information at the time of this study, 181 parties are members of the Basel Convention. From these nations, Sao Tome and Principe, and Afghanistan are the two most recent countries who ratified this convention [41].

Canada, as one of the full members to this convention, is therefore required to follow the rules and policies exerted by the convention for the transboundary movements of its hazardous wastes. Some of these general obligations are as follows:

> I: In the scope of the convention in article 1, section 1b. of the Basel convention mentions that wastes shall be considered hazardous in the transboundary movements, if "…Wastes that are not covered under paragraph (a) but are defined as, or are considered to be, hazardous wastes by the domestic legislation of the party of export, import or transit…" (Basel convention. Article 1, 1, b) [39].
>
> II: General obligations in article 4 section 1b. for export countries Basel convention mention: "…Parties shall prohibit or shall not permit the export of hazardous wastes and other wastes to the parties which have prohibited the import of such wastes, when notified pursuant to subparagraph (a)..." (Basel convention. Article 4, 1, b) [39].
>
> III: In the other part, general obligations in article 4 section 2d. ask parties to take proper measures for ensuring that "…the transboundary movement of hazardous wastes and other wastes is reduced to the minimum consistent with the environmentally sound and efficient management of such wastes, and is conducted in a manner which will protect human health and the environment against the adverse effects which may result from such movement…" (Basel convention. Article 4, 2, d) [39].

> IV: Also, general obligations in article 4 section 2e. ask parties to take proper measures to "…not allow the export of hazardous wastes or other wastes to a State or group of States belonging to an economic organization that are parties, particularly developing countries, which have prohibited by their legislation all imports, or if it has reason to believe that the wastes in question will not be managed in an environmentally sound manner…" (Basel convention. Article 4, 2, e) [39].

The above clauses are a portion of the obligations to which Canada, as a full member of Basel convention must follow. A study on "Exporting Harm: The High-Tech Trashing of Asia, The Canadian Story" from the Basel Convention shows that Canada like other convention members, does not necessarily follow the policies that members are obliged to follow. In some cases, Canada has been in violation of some of them.

As an example, the case of exported e-wastes from Vancouver to China in 2002 contains policies which have been vastly violated by Canada. As the above clauses clearly show, exporter parties are prohibited to export hazardous wastes to other countries if the importer parties prohibits the import of such wastes, in this case, China as the importer prohibited the import of electronic wastes. Canada's position in this case was to ignore categorizing e-waste under the hazardous wastes; however, even if this is their position as the exporter party, the importer party policies are still important according to the Basel Convention. Therefore, Canada cannot ignore the importer country regulations [15].

Also as the articles (4, 2, d) and (4, 2, e) address clearly, the parties need to take precautions in ensuring that the exported hazardous wastes from their nations are being handled in an environmentally appropriate manner; in the case of 2002, these articles have been violated, as Canada does not took any precaution activities [15].

Although the case that was mentioned above is outdated since it occurred 12 years ago, it is still important to note the lessons learnt from this case because there is always the possibility that similar events could happen in the future. This is true regardless of the fact that many modifications have been done on existing legislations. Also it should be mention that the above clauses are only a small part of the obligations and responsibilities that Canada as a full member needs to follow and there are many more that need to be considered.

2.8 E-waste Categories

E-waste or WEEE covers a wide range of products that contain different materials. These materials can be divided into the hazardous and non-hazardous categories. Each category consists of 1000 different substances ranging from ferrous materials such as iron and steel which account for more than 50% of the e-waste substances to other materials such as plastic accounting for 21% as well as other non-ferrous metals such as gold, silver, aluminum, platinum which account for 13% of the overall substances of the WEEE products respectively [42].

The main type of products are categorized into 10 different sections, each of which contains a wide range of different electronic products. These categories are sorted by United Nations Environmental Program and EU directive as follows [42, 43];

1. Large household appliances: i.e. Refrigerators and freezers
2. Small household appliances: i.e. Toasters and coffee machines
3. IT and telecommunications equipment: i.e. Mobile phones and computers
4. Consumer equipment: i.e. Television sets and video cameras
5. Lighting equipment: i.e. Straight fluorescent lamps and compact fluorescent lamps
6. Electrical and electronic tools (with the exception of large-scale stationary industrial tools): i.e. Tools for welding and soldering
7. Toys, leisure and sports equipment: i.e. Video games and electric toys
8. Medical devices (with the exception of all implanted and infected products): i.e. Radiotherapy and dialysis equipment
9. Monitoring and control instruments: i.e. Thermostats and smoke detectors
10. Automatic dispensers: i.e. Automatic dispensers for hot drinks [42, 43]

One issue that should not be overlooked and must be considered in all of the above categories, especially in the IT and telecommunications sectors, is the effect of hazardous chemical compounds among the 1000 substances which influence the environment, despite a less elevated effect with respect to the other factors. Gallium is one of the 200 different chemical compounds of a mobile phone and is toxic; however, it has not been documented vastly in literature. Few environmental organizations such as Greenpeace in recent years have started to document Gallium as well as other toxic materials that may have been overlooked [28].

2.9 Similar Studies

There are several quantitative and qualitative studies done in this field which have heavily influenced the core of this thesis. This section briefly outlines these studies and their findings.

In similar studies to this topic, Nordbrand [28] investigated the e-waste trade flows from the EU to developing countries. It is a concentrated study on the trade flows of the European countries, especially Sweden, and the export of the second hand goods and the e-waste illegal trade flows to the developing countries.

This paper evaluates the Euro zone policies, and the paper mentioned improvements for these regulations. It also cites illegal movements that occur in different formats such as mislabeled shipments within the import and export countries for covering up and rounding the regulations for the illegal exports, and concludes that factors such as price reduction of the valuable substances such as metal can decrease the motives of the importing countries for receiving the e-waste products.

Furthermore, Nordbrand [28] mentioned that besides all the findings, there is still a further need for future studies on this topic in the international platform for more findings in the e-waste trade flow between EU and the other courtiers.

Another similar study by Rolf et al. [27] was conducted on the global perspectives on e-waste. The paper studied different aspects of e-waste in the global format from facing challenges by different e-waste categories expansion to environmental problems that may cause in different parts of the world, especially among developing nations such as China, India and South Africa. They studied in detail various definitions of e-waste as defined by different organizations, and tried to investigate more on the role of managerial approach between developed and developing countries and the effect of domestic and international regulations on the trades between them.

In conclusion, Rolf et al. [27] mentioned three major obstacles in industrial countries that may cause an effect on the management of the end life of products, obstacles such as; lack of reliable data and appropriate international standards and finally lack of a safe WEEE recycling infrastructure.

Furthermore in another series of related studies done by Lepawsky and his colleagues in 2010 [44] and 2014 [45]. Lepawsky and Mcnabb [44] investigated mapping international flows of electronic waste, with the intent of identifying the global e-waste direction in different timing periods. They used the UN COMTRADE database for this analysis and as shown in Figure 2-1 for the year 2001 and in Figure 2-2 for the year 2006, their calculations identified the direction and the changes in the volume of the trade flow between the seven world continents.

In the mapping procedure, Lepawsky and Mcnabb [44] mentioned a few findings that are important to consider. It is important to note that the global volume estimation of the e-waste is a tricky job and it is due to this main reason that there is still a lack of a proper e-waste definition as a trade category. Because of this issue, the trade systems recognized the old and the new computers under a same trade data category, which makes the tracking hard because of the difficulty found in differentiating them. Therefore, it is because of these issues that a proxy measure is required in order to map the international regions where global trade is found to affect e-waste.

Also Lepawsky and Mcnabb [44] conducted tests incorporating the pollution haven hypothesis in order to provide correct reasoning for their observed trends as shown in e-waste with respect to the international trade. There are two ways in which this is done; one way is through the analysis of each nation's net trade balance on an annual basis against measures of relative wealth and poverty whereas the second way by means of examining each transaction between trading countries in regards to their GDP per capita.

Lepawsky and Mcnabb [44] conclude from the results of their analysis that there are four major findings. Firstly, the complexity of the e-waste global map is more than just a simple export from industrialized to developing countries. Secondly, with the help of the intra-regional trade volume, which is accounted for largest part of trade flows, e-waste tracing becomes more recognizable. Thirdly, the analysis of the pollution haven hypothesis as done by this paper provides a partial, yet important, explanation of the noted trade patterns. Lastly, their findings show that it is important to conceptualize this topic as open ended whereby it is a function of the geographic differences and the mobility as well as the accessibility for trade and traffic activities in the domains of waste to occur.

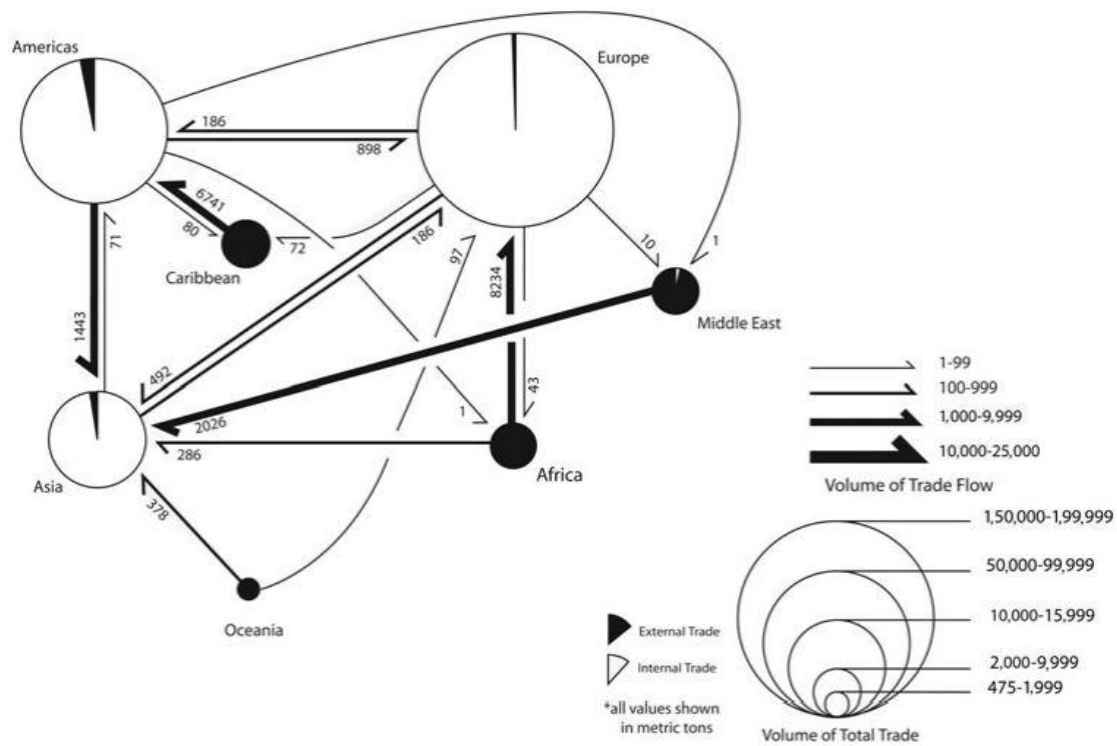

Figure 2-1: Global trade in e-waste, 2001 © John Wiley & Sons, Inc., 2010. Reproduced with permission [44, fig. 1].

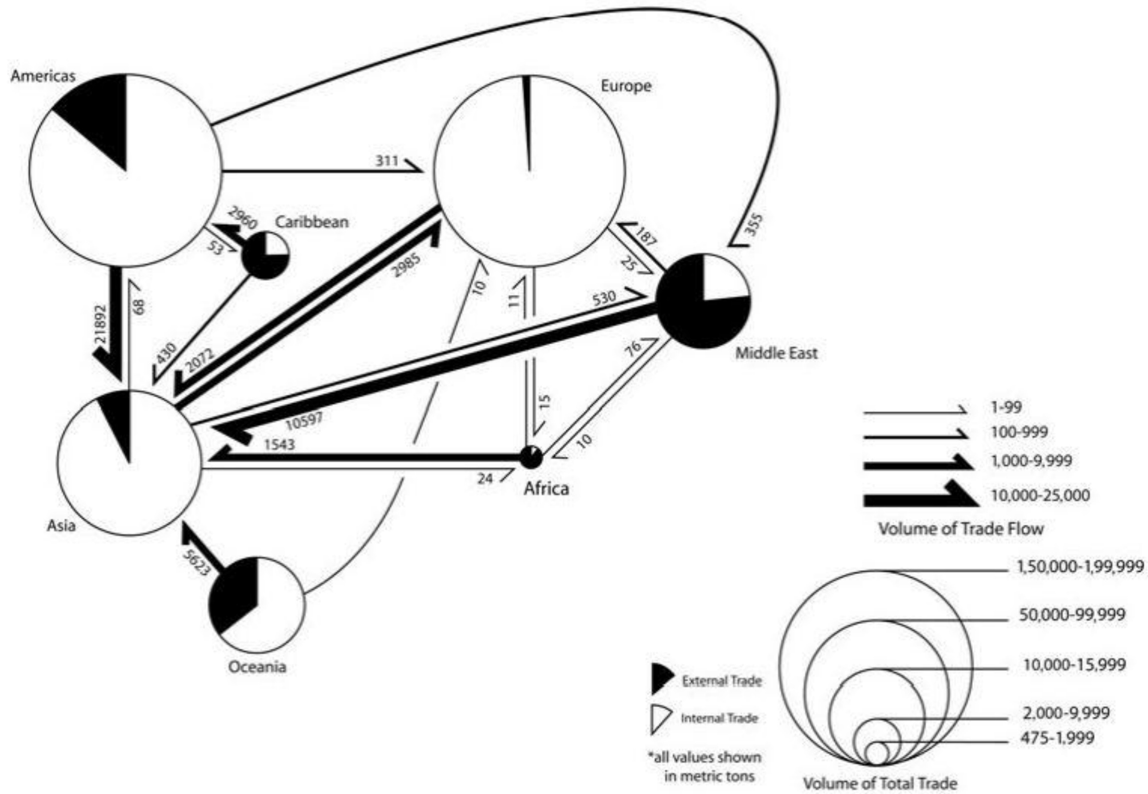

Figure 2-2: Global trade in e-waste, 2006 © John Wiley & Sons, Inc., 2010. Reproduced with permission [44, fig. 2].

Followed by Lepawsky's paper in 2010 [44] as well as in another study done entitled "The changing geography of global trade in electronic discards: time to rethink the e-waste problem." in 2014 [45], Lepawsky continued and expanded his research on the e-waste map at the international level. Lepawsky [45] mapped the global trade flow of e-waste for the two years of 1996 and 2012 in Figure 2-3 by use of UN COMTRADE database for showing the geographical changes of the electronic discards.

This investigation as done by Lepawsky [45] shows that the e-waste direction and magnitude has changed between 206 worldwide territories, from 1996 where the earliest data was retrieved to 2012.

Based on the observations, Lepawsky [45] explained two general findings. The first finding was that in 1996, trade flow from developed into developing nations accounted for a little over 35% of total trade at its climax. By 2012, this same trade only represented less than 1% of the total trade. The second finding was that between the years of 1996 and 2012, these two groups evolved as unique regional trade orientations. What was observed was that developed countries are mostly trading intra-regionally since this accounts for about 73–82% of total trade. This is in direct contrast to what has been observed in developing countries since by 2012, less than one-quarter of these nations have seen their trade being displaced to other developing countries whereas the rest have been transferred to developed countries [45].

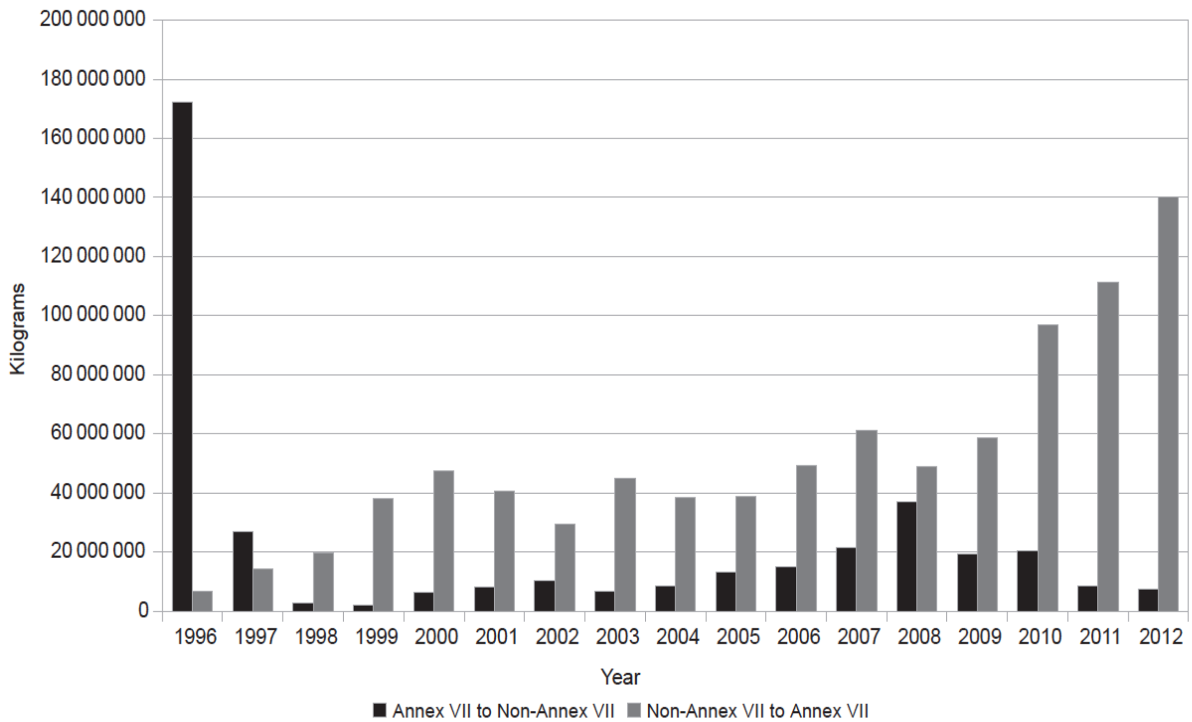

Figure 2-3: The changing geography of global trade in electronic discards, inter-regional trade, 1996-2012 © John Wiley & Sons, Inc., 2014. Reproduced with permission [45].

Among similar studies on the regulations and challenges posed by the e-waste issue in different countries involving Canada, research from Sabaa [46] on the "Electronic Waste Governance: Sustainable Solution to a Global Dilemma" should additionally be taken into consideration.

The thesis is a concentration study on the challenges, forms and future sustainable solutions for the e-wastes as human health and the environment become threatened factors in the 21st century, by understating the systems of production and use in order to discard electronics from different stakeholders. In this way, Sabaa [46] studied the institutions as well as the governmental regulations that were formed to confront this global issue by posing different national and international regulations such as banning the export of the electronic wastes towards developing countries and the mandatory recycling policies.

The Sabaa [46] thesis studied in detail parts of the Basel convention, looking at perspectives from its history and creation to its different Annexes. It also investigated the role of the Basel Ban as well as its obligation and impact on different Basel members. Furthermore, the thesis went through the WEEE legislations in different part of the world, including North America (mainly U.S and Canada), Asia (mainly China) and Europe, at the state, provincial and national levels.

It concludes that directives such as the restriction of hazardous substances (RoHS) and programs such as extended producer responsibility (EPR) at the state-level are not the only possible solutions and that the appropriate treatment for solving the e-waste generation problem is to create more improvements and reforms. On the other hand, imposing trade restrictions and instilling clean production cannot truly be the solution for confronting the global environmental crisis concerning e-waste; rather, it needs a more in-depth analysis of the functional and cultural aspects of everyday life among members of these societies in order to better understand their relation with electronic goods and services [46].

By analyzing these similar studies and to the best of the author's knowledge, there have been limited studies done on the trade flows of Canadian e-waste to the other countries. Therefore, this study can be a light for future studies on this topic. Also, by further investigating this trade flow, the Canadian environment and economy can obtain benefits in the short and the long run.

CHAPTER 3 REGULATIONS AND LEGISLATIONS

3.1 Canada's Federal E-waste Legislations

This chapter directly relates to the first defined objective of the thesis with respect to identifying the domestic and international trade factors as well as their potential effects on the trade flow of electronic waste in Canada. It will take a specific look at the regulations and legislations as the most important elements of these factors. In this way, Canada's e-waste domestic regulation at the federal and the provincial basis will be discussed followed by its comparison to the other developed countries including U.S and the European Union countries.

At the federal level, Canada has not defined any specific legislation for e-waste management. Similarly, the United States has also not defined any particular federal legislation for recycling of the e-wastes. Both countries set e-waste legislations at the provincial and state level respectively; however, the Canadian federal government indirectly influences e-waste regulations by way of the laws passed on toxic substance control [47, 48]

Despite this fact, the Canadian government gains from the e-waste strategy involving the reuse and leverage of the existing mechanisms put in place which was introduced in February 2010 by the Public Works and Government Services Canada (PWGSC) for better recycling in an environmentally sound manner for all electronic and electrical equipment. Based on Government of Canada, in just 2011/2012, the federal government spent around $1.2 billion on the disposal of a wide array of electronic and electrical equipment [12].

For better recycling the end-of-life electronic products at the national level, Canada introduced the Electronic Products Recycling Association (EPRA) in 2011, a not-for-profit association created by Canada's electronics industry, responsible for promoting and managing the e-waste products in the volunteer provinces. Currently, the program is operating in the provinces of Quebec, Saskatchewan, British Columbia, Manitoba, Prince Edward Island, Nova Scotia and Newfoundland and Labrador [49, 50].

Based on EPRA annual report in 2012, there are more than 3,000 stewards registered in the program in the entire country with up to 700 permanent collection sites and over 40 verified processors. Also based on EPRA claims, the program safely collected and recycled over 25,000 tonnes of e-waste in 2012 alone at the national level [50].

Furthermore, with respect to the legislative aspect at the federal level, the governmental approach on the e-waste issue is based on a two-tier approach:

1. Discovering new ways to confront and minimize the issue of toxic materials used in electronic products.

2. Finding methods to promote the minimization of the release of end of life toxins [51].

3.2 Canada's Provincial E-waste Legislations

In this section, the Canadian provincial legislations on e-waste will be studied by using the latest data and information with respect to their regulations and program performance, going from the largest to the smallest producer. At the moment of conducting this study, nine provinces have passed and use e-waste legislation through extended producer responsibility (EPR) for better management of the issue of end-of-life electronic products.

At the end of this section, comparisons on the policies, used programs and statistics among provinces will be evaluated in order to clearly show the impact of current legislation among these areas.

3.2.1 Ontario

The first WEEE regulation for the issue of waste in general was created in December 2004 under Ontario's Waste Diversion Act (WDA) which was passed as law in 2002, with aim of decreasing, reusing and recycling of the selected waste products [48, 52]. Following the introduction of this regulation, provincial legislation was established in April 2009 particularly for the collection, reuse and recycling of electronic products while the province launched the WEEE program and the followed the obliged legislations for a limited category of electronic products. As of April 2010, the program expanded to the 44 designated items, categorized under eight major material types, which include

"*…Display devices, desktop computers, portable computers, computer peripherals, printing, copying and multi-function devices, telephones and telephone answering machines, cellular devices and pagers, image, audio and video devices*…" [53], for legalizing the obligation of collecting and recycling the end-of-life Electrical and Electronic Equipment (EEE) under regulation of 393/04 for the entire province [53-55].

The managerial and implementation aspects of the program have been allocated to the Ontario Electronic Stewardship (OES), which is a non-for-profit industrial funding organization developed with the intent of collecting fees from industry stewards in order to better manage the WEEE program. The initiative is done on behalf of the Ontario government as well as the electronics industry. In this initiative, plans have been approved by Waste Diversion Ontario (WDO) and the Ministry of the Environment [52, 54]. Currently, more than 600 collection sites are active throughout the province due to this program [56], which is the highest number among all provinces in the country.

Furthermore, the responsibility of monitoring for tracking the quality performance of the program has been allocated to the Waste Diversion Ontario (WDO), and then gets reported directly to the Ontario ministry of the environment [54]. According to information from December 2012 from the WDO, over 200,000 tonnes of e-waste has been efficiently processed for extracting purposes in order to draw out both valuable and reusable materials due to the implementation of this program from its inception in 2009 onwards [52].

The timing of launching such a program in 2009 does not match the expansion of electronic products and the technology improvements from prior years; it would have been more appropriate to have had the program implemented in the early 2000s. Despite this fact, the program shows proper improvements over the years of operation from its creation time, from collecting 1.31 kg/capita of electronic and electrical equipment in 2009-2010 to 5.61 kg/capita and 5.67 kg/capita in 2012 and 2013 respectively, which is expected to be the highest rate in the EPS program among all provinces throughout the country [57, 58].

It should be noted that Ontario, as the most populated province in Canada, is estimated to own more than 38% of all electronic devices throughout the country. It seems reasonable that Ontario would, therefore, have the largest EPS program with respect to all other Canadian provinces, as Ontarians produce the largest amount of e-wastes annually. Looking at mobile phones alone, 81% of Ontarians own at least one mobile device which represents 42% of the Canadian population [59].

The use of electronic devices is increasing annually since new technologies are constantly replacing existing ones and that both the Ontarian and Canadian populations are on the rise; therefore, it is reasonable to assume that the growth rate of the e-waste generated in response to these changes would increase each year as well. Additionally, statistics show that 80% of Ontario households were in possession of at least one out-of-use device in 2010 alone. In the year after and in the individual's electronics rate, this number increased to the 90%, where in other words 1 out of every 10 individuals, had at least one out-of-use electronic device [59]. Based on this data and by considering the potential amount of e-waste that is expected to be produced over the coming years, the future blueprint for improvements towards the WEEE program as well as better management and monitoring of the OES and WDO should be of utmost importance for the Ontario government.

3.2.2 Quebec

Regulation Respecting the Recovery and Reclamation of Products by Enterprises (Q-2, r. 40.1) has been established as the core of e-waste regulation in November 2009 under the Environment Quality Act (EQA) to confront the issue of WEEE in the province. The legislation came into effect in July 2011 through initial mandatory policies for electronic producers to manage to collect and recycle specific electronic product categories in the province [60].

The Société Québécoise de Récupération et de Recyclage (Recyc-Quebec) is the initial responsible organization for implementing e-waste regulations in the province. This is a provincial organization which was founded in 1990 with the intent of controlling, reducing, and recycling waste in general for the province of Quebec [48].

Also to continue with this improvement process, Quebec implemented the EPRA stewardship program which was introduced and established in May 2012 and recognized by Recyc-Quebec. EPRA-Quebec claims it created 270 collection sites throughout the province in 2012, which is considered to be a great number for such a short period of time since its inception [50]. However, despite this large number of collection sites that have been created, the province ranked last among the other provinces with respect to its performance for having the lowest collection rate of the 1.30 kg/capita based on the latest data released by the EPRA for the 2013 [61].

The sites are responsible for the collection of end-of-life electronic products under twelve major categories free of charge. These categories include "…*Portable Computers, Desktop/Countertop Computers, Computer and Video Game Peripherals, Display Devices, Cellular Devices and Pagers, Desktop Printers/Scanners/Fax Machines/Copiers and Multi-Function Devices, Floor-Standing IT Equipment, Personal/Portable Audio/Video Systems, Non-Portable Audio/Video Systems, Vehicle Audio/Video and Navigation Systems, Home Theatre in a Box, Non-Cellular Telephones and Answering Machines*…" [62]. From October 2012, environmental handling fees (EHFs) have been introduced in the province and EPRA-Québec is responsible for collecting these fees [63, 64].

3.2.3 British Columbia

The first waste legislation movement in B.C. started in July 2004, after creation of the Environmental Management Act (EMA) by the Ministry of the Environment. The movement continued by the introduction of British Columbia's Recycling Regulation in October of the same year for recycling and the waste category in general for protecting the environment in the province [65]. Under this act, electronic producers must be approved as of August 2007 by one of the provincial electronic product stewardship programs (PSPs) in the province; either the Electronic Products Recycling Association (EPRA), formerly known as Electronic Stewardship Association of BC (ESABC) which is operated by the Encorp Pacific, or Canadian Wireless or Telecommunication Association [50, 66].

Despite the fact that the EPRA (formerly known as ESABC) was active in the province since 2007, the province officially established and implemented its own Electronic Products Recycling Association in 2011 [67]. Since its official establishment, the association claims a couple of successful e-waste collection reports of 4.7 kg/capita for 2011 and 4.8 kg/capita for 2012 [50, 68]. This number in 2013 increased to the 5.04 kg/capita collection level, which put B.C. the same as the Nova Scotia in the rank second among the other member provinces [61]. This is taking into account that this number for 2010 and before the official change from ESABC to EPRA was only 3.8 [68].

It must also be mentioned that, with respect to the advantages of the recycling regulations and its implementation system in the province, the main positive point to be retained is the responsibility of recycling and its financial liabilities on the producers and consumers involved in the transaction of electronic products rather than placing these burdens on the tax payers in society. Therefore, following these regulations, it is the responsibility of the producers to efficiently manage their products end-of-life [69].

In B.C, as well as in some other provinces, the recycling implementation of the electronic and electrical equipment (EEE) has been introduced in different phases according to the schedule set out for various products. The phases include five time periods with different electronic products, starting in 2007 by "*…televisions, computers, computer monitors, keyboard, mice and other peripherals and printers…*" [69]. After the first two years of implementation of this phase from 2007, there has been about 4,200 metric tonnes of e-waste that has been prevented from entering landfills; currently, about 1200 metric tonnes of e-waste is diverted on a monthly basis [34].

The second phase has been implemented three years later in 2010 for electronics such as; "*…Cell phones, audio-visual and consumer equipment, thermostats, batteries products and residential compact fluorescent light (CFL) bulbs…"* [69], followed by the third and the fourth phases being implemented in 2011 for products such as smoke detectors and small appliances [69].

The fifth and final phase with a broader range of products list introduced and came into effect in 2012, included "*…large appliances, electrical and electronic tools, medical devices, automatic dispensers, lighting equipment, toys, leisure and sports equipment, monitoring and control instruments, and telecommunications equipment…*" [69].

3.2.4 Alberta

Despite the fact that Alberta is ranked fourth among the other provinces with respect to the production of electronic waste in the country, Alberta is the premier leader in the e-waste regulatory throughout the country. Alberta was the first province to establish its own e-waste management program under Environmental Protection and Enhancement Act (EPEA) and based on the Canadian Council for Ministers of Environment (CCME) principles in October 2004 serving as a pioneer in this domain [51].

The program is run by the Alberta Recycling Management Authority (ARMA), in accordance with the Designated Material Recycling and Management Regulation and Electronic Recycling Bylaw, for mandating electronics producers to pay an environmental handling advance disposal fee for a select basket of electronic products before selling into the market [66, 70].

These surcharges are allocated to all suppliers who import or produce designated new electronics into Alberta's electronics market, and mandates all the electronics suppliers to be registered by ARMA regardless of, despite the fact that they may be subject to paying the required stewardship fees [66].

Regarding its performance, e-waste collection and recycling statistics show that the success rate of the program varies in depending on the year. As of the latest data for 2012/2013, the program has succeeded in processing 4.67 kg/capita of e-waste, which is the equivalent of 17,280 metric tonnes. It should be noted that this number is very close to the processing rate of three years earlier 2009/2010 where the processing rate was 4.57 kg/capita. Aside from these mentioned results, for the years of 2008/09, 2010/11 and 2011/12, the processing rate were lower, sitting at 4.30, 4.28 and 4.40 kg/capita respectively [71]. Also on the forecasting side, ARMA predicts a forecast of 4.79 kg/capita for the current year of 2013/2014 as a preparation stage for jumping to the coming years processing and collection target rate of 5 kg/capita [72].

With respect to ARMA's claims, there has been a significant amount of computer equipment and television devices that have been recycled by Albertans since the start of the program, totaling to approximately six million units. Due to the program, it is estimated that 129,000 metric tonnes of recyclable material such as metal, plastic, and glass have been effectively extracted and shipped into the marketplace for the future use [73].

Also based on ARMA report, more than 350 collection sites are currently operating in the entire province for the collection of the designated list of electronics waste. This consists of; "…*Televisions, computer monitors, CPUs, keyboards, cables, mice, speakers, laptops, notebook computers and printers*…" [73].

3.2.5 Manitoba

One of the provinces that recently passed law and operated the EPRA program for controlling and decreasing e-waste is Manitoba. Although the province gains from the initial regulation for reducing solid wastes in general since 1990 under the Waste Reduction and Prevention (WRAP) act, the direct regulation for the electronic waste came into force under WRAP in February 2010 also known as Manitoba's Electrical and Electronic Equipment Stewardship Regulation [66, 74].

Under this regulation, province set the planned target date for establishing an industrially-led program for April 2011 with implementation coming into effect as of April 2012 [66]. Therefore, in order to reach these targets, in 2011 the EPRA has been started up by the Retail Council of Canada (RCC) and the members of the Electronics Product Stewardship Canada (EPSC), and has been launched in August 2012 [75, 76].

Based on the EPRA claims, the Manitoba program successfully recycled and collected over 1349 metric tonnes of end-of-life electronic products without causing any harmful effects to the environment from the beginning of its existence in August 2012, of which 830 metric tonnes comes from the first five months of the program operation [50, 76]. The 2013 report shows that this number increased to the 3,026 metric tonnes, which is the equivalent of the 2.38 kg/capita [61]. Furthermore, it is estimated that as of that date, the program succeeded in attracting more than 380 stewards to join the association [76].

Similarly to the other provinces, Manitoba's EPRA program only collected the designated basket of electronics for the purpose of recycling. At the time of conduction of this study, the accepted list is limited to the following items: "*…Display Devices, Desktop Computers, Portable Computers, Printers/Scanners and Fax Machines, Computer Peripherals, Non-Cellular Phone and Answering Machines, Home Audio/Video Systems, Home Stereos Systems or Components, Vehicle Audio/Video System, Counter Top Microwave Ovens, Personal Portable Audio/Video and Floor Standing Multi-Function Devices…*" [77].

3.2.6 Saskatchewan

The Waste Electronic Equipment Regulations, which came into effect in February 2006, was established under the Environmental Management and Protection Act of 2002 as the core regulation for electronic waste in the province. The regulation has been amended in 2009 [78].

On the operational side, the Saskatchewan Waste Electronic Equipment Program (SWEEP) was created in late 2006 and came into effect in February 2007 by the government of Saskatchewan for coordinating the collection and recycling of the end-of-life electronic products [79, 80].

In April 2013, members of SWEEP have passed the motion of dissolving SWEEP entirely in favor of integrating as part of the EPRA in order to find more efficient ways for diverting the end-of-life of designated waste electronics coming from landfills as well as illegal exports, among other efficiencies gained by becoming a part of a program on the national level. Hence, EPRA/SWEEP has been formed [81, 82].

From a performance point of view based on claims by SWEEP, since its establishment in 2007, the program successfully collected more than 15,000 metric tonnes of the end-of-life electronic products and prevent them from landfill disposal. From this amount, more than 6,000 metric tonnes is a result of the last two years of operation [82]. Also based on the EPRA report, the province had a collection rate of 3,288 metric tonnes, which is equivalent to 2.95 kg/capita for 2013 [61].

The program currently accepts the designated end-of-life electronics in 71 recycling plants across the province and Saskatchewan's Ministry of Environment has the responsibility of surveying program performance as well as ensuring that industrial compliances with the Waste Electronic Equipment Regulations are met and satisfied [79].

The SWEEP list of collection electronics for the purpose of recycling is almost the same as the Manitoba EPRA, with four differences. In Manitoba there are two additional collection lists of Floor Standing Multi-Function Devices and Counter Top Microwave Ovens which is non-existent in Saskatchewan’s list, and in front in Saskatchewan EPRA, there is the list of Home Theater In-A-Box (HTB) Systems which does not exist in Manitoba’s EPRA collection items. Additionally in Saskatchewan, the cell phone category is managed by the Canadian Wireless Telecommunications Association (CWTA) which is not the case in Manitoba [77, 83].

3.2.7 Nova Scotia

According to the government of Nova Scotia, the e-waste regulation in this province is the first of its kind in Atlantic Canada [84]. The Electronic Product Stewardship Regulations has been designed and proposed under the sections 18J to 18Q (Electronic Products Stewardship Program) in the amended version of Solid Waste-Resource Management Regulations in February 2007; it has been approved as law in July 2007 for recycling and diverting the end-of-life electronics from landfill disposals throughout the province [84-86].

The program came into effect in two phases for the collection of the designated basket of end-of-life electronic products. The first phase began in February 2008 and includes the following categories: (Televisions, Notebook and Desktop computers and their lateral components, Computer monitors and printers). In February 2009, the second phase began and consists of the following categories: "*…Computer Scanners, Audio and video playback and recording systems, Telephones and fax machines, Cell phones and other wireless devices…*" [86], by the Atlantic Canada Electronic Stewardship (ACES) which is the organization responsible for managing the program, with the exception of cell phones and other wireless devices. These particular devices are under the control of the Recycle My Cell program, which is a part of the Canadian Wireless Telecommunications Association (CWTA) [84, 86, 87].

Currently the list has slightly been expanded to include four additional categories based on the Nova Scotia EPRA; these include: "*…Personal or Portable Audio/Video Systems, Vehicle Audio/Video Systems (After market), Home Theater in a Box (HTB) Systems and Home Audio/Video Systems…*" [88].

It is estimated that in 2003 alone about 4500 metric tonnes of e-waste has been generated in the province. Based on this finding, the e-waste generated for 2010 was predicted to be almost 5000 metric tonnes [50]. For controlling the generation of the e-waste on an annual basis, the EPRA has succeeded in collecting 4719 metric tonnes of e-waste, the equivalent of 4.97 kg/capita in 2012. This is higher than the 4354 metric tonnes collected in 2011, the equivalent of 4.61 kg/capita [87]. This improvement increased in the year after as well, as the province succeeded in collecting 5.04 kg/capita in 2013 [61].

This program currently accepts the designated end-of-life electronics in 37 drop-off plants across the province. Nova Scotia Environment, which oversees climate change and protecting the environment, has the responsibility of surveying program performance in order to ensure that industrial compliances are maintained and put into effect with the Waste Electronic Equipment Regulations [87].

3.2.8 Newfoundland and Labrador

Following the amendment found in the Waste Management Regulations, 2003 under the Environmental Protection Act that has been taken into effect as of October 2012 (O.C. 2012-288), Newfoundland and Labrador became the last province in Canada to introduce e-waste regulations for managing, collecting and recycling the WEEE [89].

In August 2013, the EPRA has been launched in the province and Newfoundland and Labrador. The EPRA has been designated as the organization responsible for managing the end-of-life electronics program in the province [90]. Based on the fact that this has recently come into effect, there is no report that has been published regarding the collection and recycling performance of the program, though it is expected that the first year performance report of the program will be published by the EPRA by the end of 2014.

Primarily, it was estimated that the EPRA will begin establishing somewhere between 17 and 19 permanent drop-off locations covering the entire province of Newfoundland and Labrador, effective as of the first year of this initiative, based on the EPRA report [90]. But, based on the most recent data available on the Newfoundland and Labrador EPRA website, the program has succeeded in running 21 collection sites throughout the province from the conduction of this study [91], and currently the designated collection list of electronics is the same as what is found in Nova Scotia [88, 92].

3.2.9 Prince Edward Island

The Materials Recycling Regulations, which was passed under the Environmental Act and has come into effect in July 2010, is the first regulation for end-of-life electronics disposal and recycling in the province for diverting designated end-of-life electronics from the landfills disposal and preventing their illegal exportation to other countries [66, 93].

In the same year, Prince Edward Island has come into an agreement with Atlantic Canada Electronics Stewardship (ACES) so that the development, effectiveness and administration of an end-of-life electronics stewardship program is applied all over the province. As a result, ACES became the organization responsible for managing the program [48]. Since July 2013, both the provinces of Prince Edward Island and Nova Scotia have officially merged into national EPRA [61].

Based on the EPRA report for 2013, the program succeeded in collecting and recycling 645 metric tonnes, which is the equivalent of 4.44 kg/capita of the designated end-of-life electronic products in this year [61]. This is almost the same as the year before where 649 metric tonnes, which is the equivalent of 4.44 kg/capita, was also collected and recycled [50]. This is in the situation that from July 2010 to March 2011, statistics show collection rates were lower at 3.81 kg/capita, which is the equivalent of 543 metric tonnes [94].

In order to monitor the program's performance, the Prince Edward Island Department of Environment, Energy and Forestry has been designated as the organization responsible for ensuring that the performance and industrial compliances are satisfied according to what is specified in the Materials Recycling Regulations [94].

As of conducting this study, six drop-off locations are operating for the collection of the designated list of end-of-life electronics in the province [95]. Additionally, the designated collection list of electronics is currently the same as that found in the EPRA lists in Saskatchewan, Nova Scotia as well as Newfoundland and Labrador [83, 88, 92, 96].

3.3 Non E-waste Regulated Provinces

Despite the fact that it is beneficial for all Canadian provinces and territories to implement environmental protection legislations and policies for controlling waste in general, this study has found that New Brunswick, Yukon, the Northwest Territories, and Nunavut have not yet defined any specific regulations regarding the e-waste issue.

Although province of New Brunswick gains from having a limited environmental stewardship program, it presently has not been expanded to the category of e-waste. In this province, the program is only designed for the collection and recycling of tires, paint, oil and glycol [97].

One of the possible reasons that legislation has not been created may be due to the low population found in these areas because they have been ranked as the lowest populated areas in the country. Therefore, it is not surprising to see that this issue is not highlighted in these areas.

3.4 Legislations Comparison

3.4.1 Provincial Legislation Comparison

This section is divided into two main categories of legislation similarities and differences among provinces that gain from the e-waste regulation.

From a legislative perspective, one of the main likelihoods is the fact that the responsible association for managing the stewardship programs in eight out of the nine provinces which gain from the e-waste regulation is the electronic products recycling association (EPRA), with exception of Alberta since Alberta Recycling is the association that is in charge.

In contrast, the differences are divided into four main categories which include: legislation launching and implementing time frame, designated electronics basket, performance/efficiency comparison and total program cost per metric tonne of collection. Table 3-1 shows the establishment and implementation time period of WEEE for nine provinces. As it can clearly be seen on the launch timing and implementation period, Alberta can be ranked as the province with the oldest launch date whereas Newfoundland and Labrador is the most recent.

Table 3-1: Provincial launching and implementation time frame differences.

Province	Launch Date	Implementation Period
Alberta	October 2004 [13]	October 2004 [98]
Ontario	December 2004 [52]	April 2009 [98]
Saskatchewan	February 2006 [78]	February 2007 [98]
British Columbia	December 2006 [13]	August 2007 [98]
Nova Scotia	July 2007 [85]	February 2008 [98]
Quebec	November 2009 [60]	July 2012 [98]
Manitoba	February 2010 [66]	August 2012 [98]
Prince Edward Island	July 2010 [93]	July 2010 [98]
Newfoundland and Labrador	October 2012 [89]	August 2013 [98]

In the second category, the designated basket of electronics in general is similar to that among most of the provinces; it is the same in Saskatchewan, Nova Scotia, Newfoundland and Labrador as well as Prince Edward Island.

Despite this similarity, there are a few differences that are obvious as well. In Alberta, which has the smallest list of designated electronics for collection and recycling, the list is only narrowed down to a few electronics categories consisting of; "…*Televisions, computer monitors, CPUs, keyboards, cables, mice, speakers, laptops, notebook computers and printers*…" [73].

Another difference comes from British Columbia. Although this province has a similar recycling list of electronics compared to other provincial programs, the list of accepted products covers three more electronics devices which consist of: Musical Instruments, Medical Devices and Electronic Toys; this is not the case among other provinces. Also with respect to other differences, Manitoba's Counter Top Microwave Ovens list is another other unique element in the accepted list of electronics not found in other provinces.

In the performance/efficiency collection comparison among the provinces, Ontario has the highest performance rate among other provinces with the 5.61 kg/capita collection rate for 2012 and 5.67 kg/capita record for 2013. The provinces of British Columbia and Nova Scotia follow with the same collection rates of 5.04 kg/capita for 2013 per province.

Alberta comes in third with 4.67 kg/capita, then Prince Edward Island with 4.44 kg/capita, making it the last province with a collection rate above 4 kg/capita. The provinces at the bottom of the performance list with collection rates of less than 4 kg/capita includes the provinces of Saskatchewan, Manitoba and Quebec with the collection rates of the 2.95, 2.38 and 1.30 kg/capita respectively. These are weaker performances when compared to global collection rates such as those from European countries and even the other internal provinces.

Table 3-2 shows the provincial end-of-life electronics collection ranking for 2012 and 2013. As it can clearly be seen, Ontario can be ranked as the province with the highest collection rate whereas Quebec was the lowest one.

For the collection rate column from 2012, it should be noted that the provinces of Manitoba and Quebec do not have any reported data. This is due to the fact that they have recently entered into the EPRA program and the implementation period, which began at the end of 2012.

Table 3-2: Provincial end-of-life electronics collection rate ranking for 2012 and 2013.

Ranking (2012)	Collection Rate, (Kg/Capita, 2012)	Ranking (2013)	Collection Rate, (Kg/Capita, 2013)	Province
1	5.61 [58]	1	5.67 [58]	Ontario
3	4.80 [50]	2	5.04 [61]	British Columbia
2	4.97 [50]	2	5.04 [61]	Nova Scotia
5	4.40 [72]	3	4.67 [72]	Alberta
4	4.44 [50]	4	4.44 [61]	Prince Edward Island
6	2.85 [82]	5	2.95 [61]	Saskatchewan
	No data available	6	2.38 [61]	Manitoba
	No data available	7	1.30 [61]	Quebec

Table 3-3 shows the total program cost per tonne of collection among the provinces for 2013, from the cheapest collection cost to the most expensive collection cost. As can be seen, Ontario even in the collection cost gains from having the lowest cost rate, which gives this province the best rank for having the cheapest collection cost system. On the other hand, Saskatchewan with the highest cost has the most expensive collection system.

Table 3-3: Provincial total program cost per tonne of collection for 2013.

Total program cost per tonne	**Province**
$990	Ontario [58]
$1,055	British Columbia [61]
$1,112	Prince Edward Island [61]
$1120	Alberta [72]
$1,134	Manitoba [61]
$1,207	Nova Scotia [61]
$1,354	Quebec [61]
$1,731	Saskatchewan [61]

3.4.2 U.S. vs. Canada

Despite the fact that countries such as the United States and Canada are those that have state and provincial legislations respectively for electronic and hazardous wastes, their comparison shows few interesting differences between the provincial, national and even international levels.

At the international level with respect to a country's responsibility concerning international regulations, the main difference is that the Basel convention was ratified by Canada whereas the U.S. did not do so. Therefore, this makes Canada incur more restrictions with respect to the e-waste export to the non-OECD countries compared to the U.S. But on the other hand, the main difference is on the way in which e-wastes are managed, because at the federal level in the U.S., there is a large dependency towards e-scrap, making it a hot market. Many materials that are brought in can be of high value and many people throughout the United States are rewarded well for their findings. This is in contrast to Canada where e-waste runs under a social program fuelled by the use of eco-fees, despite the fact that in most cases individual recycling services are for profit organizations [99].

One of these differences at the provincial or state level includes the type of programs that are being used. As of an example, among all states that have introduced similar programs as to that of the EPSC among Canadian provinces, California and Maine are using similar programs with slight modifications. An example of such programs is the use of the point of purchase environmental handling fees, which is a similar program but with a different implementation. In Maine, fees vary because they depend on the market share from individual manufacturers, something that is not applied in Canada [48]. On the other hand, a number of U.S. states, regardless of whether a recycling legislation is in effect, have imposed embargos on used electronic disposal coming from landfills [100], another measure which is not in effect in Canada, with the exception of the province of Nova Scotia.

In regards to the legislation framework for hazardous waste including e-waste in the United States, dates back to 1976 when the federal law governing the removal of solid and hazardous waste under the platform of the resource conservation and recovery act (RCRA) was taken into effect. This law has been amended three times later on in 1984, 1992 and 1996 in order to implement several modifications, such giving more authority to the U.S. Environmental Protection Agency (EPA) in order to regulate the disposal of hazardous wastes, including e-waste, for additional flexibility to implement appropriate policies, or designing more dynamic regulations in order to implement effective land disposal methods of certain wastes, or even allow what is stipulated in the RCRA to be enforced at Federal facilities [101].

3.4.3 Canada vs. European Union

Europe, without a doubt, has one of the best reputations with respect to other regions throughout the world for monitoring, controlling and managing this issue; it is even ranked higher than North America, implying that countries including Canada are inferior in comparison. Therefore, an investigation comparing and contrasting the policies implemented between Canada and Europe can prove to be beneficial for Canada.

One of these differences is the unique legislation of the EU as a union and its mandate for the member countries to follow, as the decisions are made in group and must be followed by the members. This is in contrast to what is found in Canada as legislations are made on a provincial basis and centralized by the federal government.

The other difference is from the basic regulation and direction. The Restriction of Hazardous Substances (RoHS), was a fundamental law passed in 2003 for restricting and prohibiting the producers of the electrical and electronic equipment in the European Union for using the six hazardous materials in the manufacturing of their new electronic products from July 2006 onwards. Such substances include: Lead, Mercury, Cadmium, Hexavalent Chromium, Polybrominated Biphenyls and Polybrominated Diphenyl Ethers [102]. This list of hazardous substances has been identified by the Canadian federal government and has been listed under toxic substance control in 1988 [103]. Despite this fact, Canada does not bring the same mandate as the EU does to the producers of the new electronic products in the country.

The other comparison on the performance side shows a few interesting points as well. As Figure 3-1 shows, the collection weight of the WEEE in EU states on average is heavier than the Canadian provinces on an annual basis. This is the situation that the future collection target rates have been set to rise in most of the EU states as opposed to the Canadian provinces, especially in the Northern, Central and Western European states.

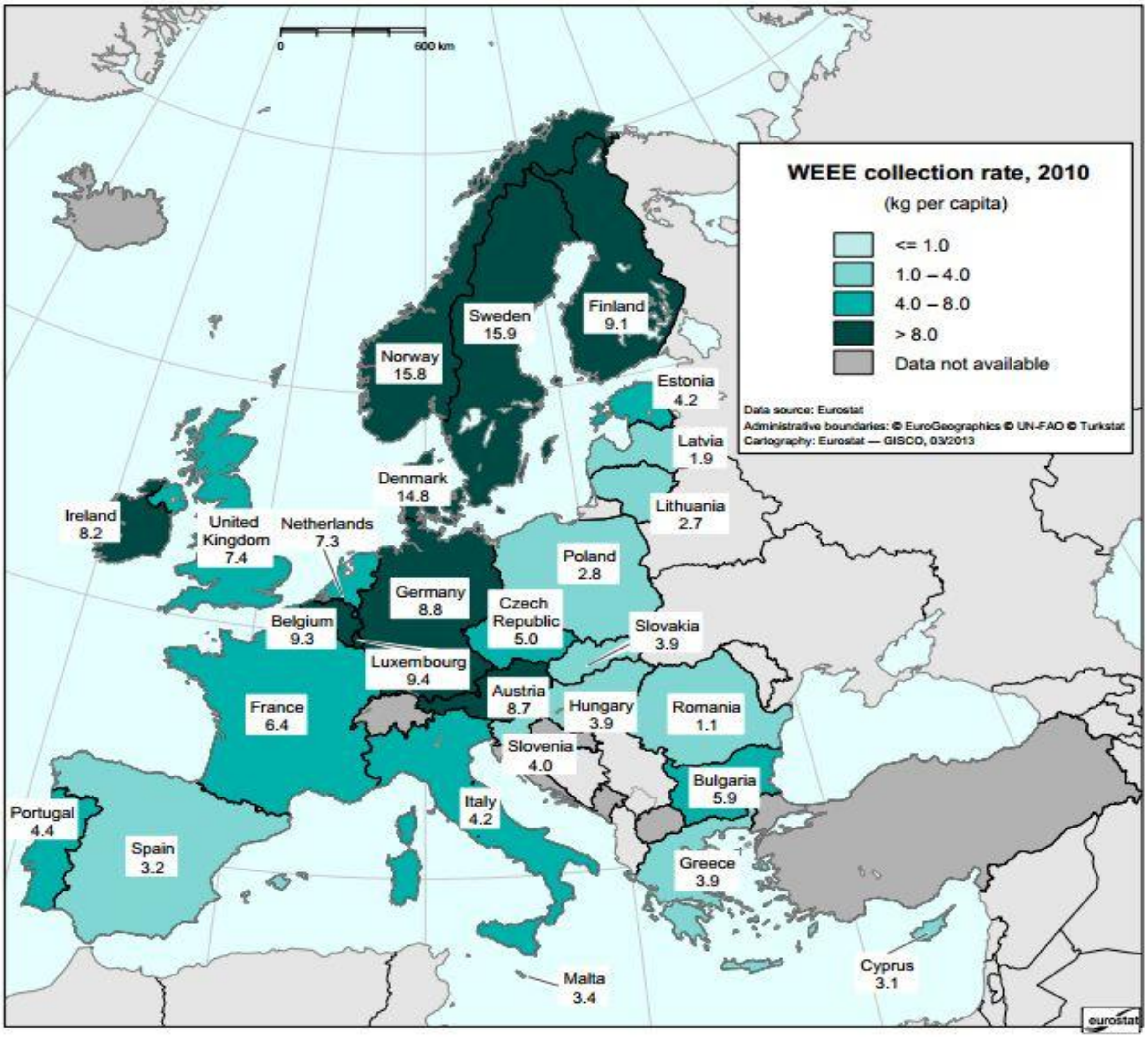

Figure 3-1: WEEE collection rate, 2010 © Eurostat, 2013. Reproduced with permission [104].

In the situation that the EU sets its minimum collection WEEE target rate at the 4 kg per inhabitant annually by 31 December 2015 and half of the member states have a collection rate of more than 5 kg per person in 2010, most Canadian provinces set their ultimate target rate in recent years between 4 to 5 kg per inhabitant. Therefore, it is expected to see this gap widen in the near future, as the modification of the EU waste directive in August 2012 set a new target collection rate of 85% for its members to be in effect by 2019 [104, 105].

The other difference to note is based on the e-waste collection designations. As in the EU, the e-waste categories are specifically designated by the 2002/96/EC directive for the EU states into ten different categories that have been listed in chapter one [102]; in contrast for Canadian provinces, the collection list is assigned by each province separately.

Generally speaking, the e-waste legislations in the EU is well developed compared to other parts of the world in recent years. With respect to performance as revealed by statistical data, the collection and the recycling rates had the great improvements as well.

CHAPTER 4 DATA ANALYSIS

4.1 Collected Data

In this study, the data that has been used for identifying the e-waste trade flows in Canada is the same database that Lepawsky and his colleagues used in two papers of 2010 [44] and 2014 [45] for mapping the global e-waste trade flows.

The data has been extracted from the UN Comtrade database, Specific Harmonised System (HS) category 2002 code 854810 entitled (Waste and scrap of primary cells, primary batteries and electrical accumulators), from 1996 to 2013, since this year range contains all data available from both ends of the date spectrum. The complete list of UN Comtrade Harmonised System (HS) waste categories is available in APPENDIX A.

This database has been used based on the fact that, at the time of writing this research and to the best of author's knowledge, there is no other database that is similar to 854810 in existence that can be used as a proxy for measuring e-waste at the international or domestic levels. Therefore, there is no complete e-waste data found that can be used for measuring the e-waste trade flows and it is therefore necessary to use a proxy for sampling a database for evaluating this flow.

However, it should be also noted that this issue does not necessarily mean that the database is an absolute representation of all e-waste categories in Canada. Therefore, the terms used in this study are only in reference to this sample database and its analysis with the assumption that this database can be a proper proxy of a bigger picture and are not referring the total absolute e-waste flows in Canada.

Based on this fact, this study uses UN Comtrade HS code 854810 as the main database and the proxy for assuming the global e-waste flow of Canada. As shown in Table 4-1, the following are the assumptions and the reasons for using this database:

Table 4-1: UN Comtrade Dataset Code 854810 Advantages

UN Comtrade Dataset Code 854810 Advantages	
1	This is the only available resource as found in the UN Comtrade dataset that is pertinent to electronic discards [45].
2	Includes trade reports from both exporter and the importer parties. It is therefore possible to trace the geography of the trade.
3	The data are related to time and are available for 18 years from 1996 to 2013. Therefore, it is possible to observe the time of the trades and to forecast a short time period in the future.
4	The given information gives insight with respect to the magnitude, direction and appropriate structure for trade that are in alignment with the results as provided by other studies that use a diverse range of methods and sources [45].
5	The data is not permitted to be a direct measure of the trade aspect which is of utmost importance that revolves around reuse, repair and refurbishment. It is also important to note that no existing Harmonised System (HS) code can fulfill this request since such a code is non-existent [45].

Aside from all of these advantages, the UN Comtrade database has its own disadvantages as well. Table 4-2 categorizes these weaknesses.

Table 4-2: UN Comtrade Dataset Code 854810 Disadvantages

UN Comtrade Dataset Code 854810 Disadvantages	
1	Limited period of time data availability (1996-2013).
2	The database represents a small portion of e-waste materials and includes only the waste and scrap of primary cells and batteries as well as electrical accumulators. Therefore, it does not include the other important categories of the scrap or waste electronic materials such as different types of displays, TVs, computer monitors, etc [44].
3	The database doesn't mention anything regarding the condition of the materials nor the ends that traded commodities are required (such as; recycling, recovery, reuse or final disposal) [45].
4	The variation in the amount of data reported by different countries in different years that causes data disperses [44]. This could be due to several reasons (for more detail, see the analysis of the data section).
5	The database does not include any report regarding the illicit trade flows.
6	The trade volume and values both at the same time are not available in some occasions for the same country year report. For example, Canada import value from Japan in 2013 is available but the trade volume is missing for the same year in the database.

As mentioned earlier, only the waste and scrap of primary cells, primary batteries and electrical accumulators are the three main categories of this database. Therefore, in order to obtain a better understating of these categories, it is important to take an initial look at the batteries recycling regulations in Canada as well.

In Canada, the recycling of batteries is divided into two general categories of primary and rechargeable batteries. Based on data from Environment Canada, there is a recycling program for batteries that is voluntary among select provinces. Out of all Canadian provinces, only British Columbia, Manitoba and Quebec have regulated and mandated the collection and the recycling of rechargeable batteries [106]. For the primary portable batteries, the situation is slightly different as Ontario is also included in the mentioned provinces; therefore, four provinces gain from a mandatory collection and recycling programs [107].

4.2 Methodology

Tracing the e-waste trade flow and identifying its illegal trade is a challenging issue due to a variety of reasons. As mentioned in a vast amount of literature in this field and especially as stated by Lepawsky and his colleagues in 2010 [44] and 2014 [45], the most important reason is due to the lack of a proper international definition for e-waste on a global basis. Since there is no data category defined to the best of author's knowledge for the electronic waste in the global databases.

Besides the lack of a definition for electronic waste and a global standard database in this field, there are other problematic issues as well as Lepawsky mentions that are cause hardships for measuring the e-waste trade flows. These issues include a lack of data in that categorize used and new electronics in different categories for distinguishing each other. Therefore, it is mainly due to this weakness of data that is difficult to identify the exact illegal trade flows [45].

By taking all the above challenges and the data limitations into consideration, this study tries to simulate the e-waste trade flow map for Canada from 1996 to 2013 by using proxy data that have been discussed earlier. In this way, a different methodology has been used on the data chosen compared to other similar studies that use the same UN Comtrade database. As in this research, data trade values have been used for the analysis instead of the trade volume.

Therefore, the U.S dollar has been used due to this fact that based on the authors observations on the UN Comtrade database, most of the trade volumes are missing or have never been reported by different countries, mainly from Canada. Therefore, the trade volume could not be used as a proper proxy due to lots of data missing and the data value chosen instead.

Firstly, the author collected trade value data based on the reports released by Canada in the last 18 years. After observing the missing data for some years for many countries, for comparison purposes, the author also collected data reported by the all other countries that exist on the UN Comtrade database list, which are those who reported e-waste exports or imports to or from Canada for the same time period. Furthermore, these reports have been compared and analyzed for identifying the gaps on the trades that has been reported differently.

In continuation, a new database has been created by the author including the largest amount of data value reported by one of the trade parties between Canada and its trade partner for mapping Canada's e-waste trade network.

The largest amount has been chosen due to the assumption that in the reports of the hazardous wastes such as electronic waste, due to the nature of the trade, countries would prefer to report a lower amount than the real one. Therefore none of the importer or exporter countries gain from reporting a larger amount; hence, one with the larger number can be assumed to be a more likely real number.

Furthermore, all the collected data has been converted from the current dollar value to the constant dollar value. This has been implemented through the use of the annual rates from the Consumer Price Index (CPI) in United Sates for all years prior to 2013 in the database.

For this purpose, the current dollar value has been multiplied by the 2013 CPI index rate (i.e. the base year), and then divided by the CPI index rate of the specific year which needs to be converted to constant value.

4.3 Analysis of the Data

In this section, the finding and the results from the analysis of the data are going to be discussed in five main sections:

- The proxy e-waste flow in Canada with respect to the rest of the world from 1996 to 2013
- Canada's proxy e-waste trade network for 1996 and 2013
- Canada's top e-waste trade partners (from the average annual trade value and the overall number of trades)

- Identified gaps between the bilateral e-waste trade information released by Canada and the other trade partners
- Illicit trades

4.3.1 Canada's e-waste Trade Flow

As analysis of the proxy data in Figure 4-1 shows, Canada's e-waste trade flow has dramatically changed from an exporter country between 1997 and 2006 to a net importer from 2007 onwards. Figure 4-1 also reveals that this sudden change has been followed by a big jump by the start of 2009 and the years after.

The data shows that import rose by more than 6 times, from $17.6 million in 2009 to over $105.6 million in 2011. For the same period, export increases only twice as much, increasing from $10.8 million to $21.7 million.

This expansion was not steady and has slowed down in 2012 for both the import and export sections. The import has dropped to $88 million in 2012 yet has increased to $91 million in the following year whereas the export has increased to $33 million in 2012 then dropped again to $26 million the following year.

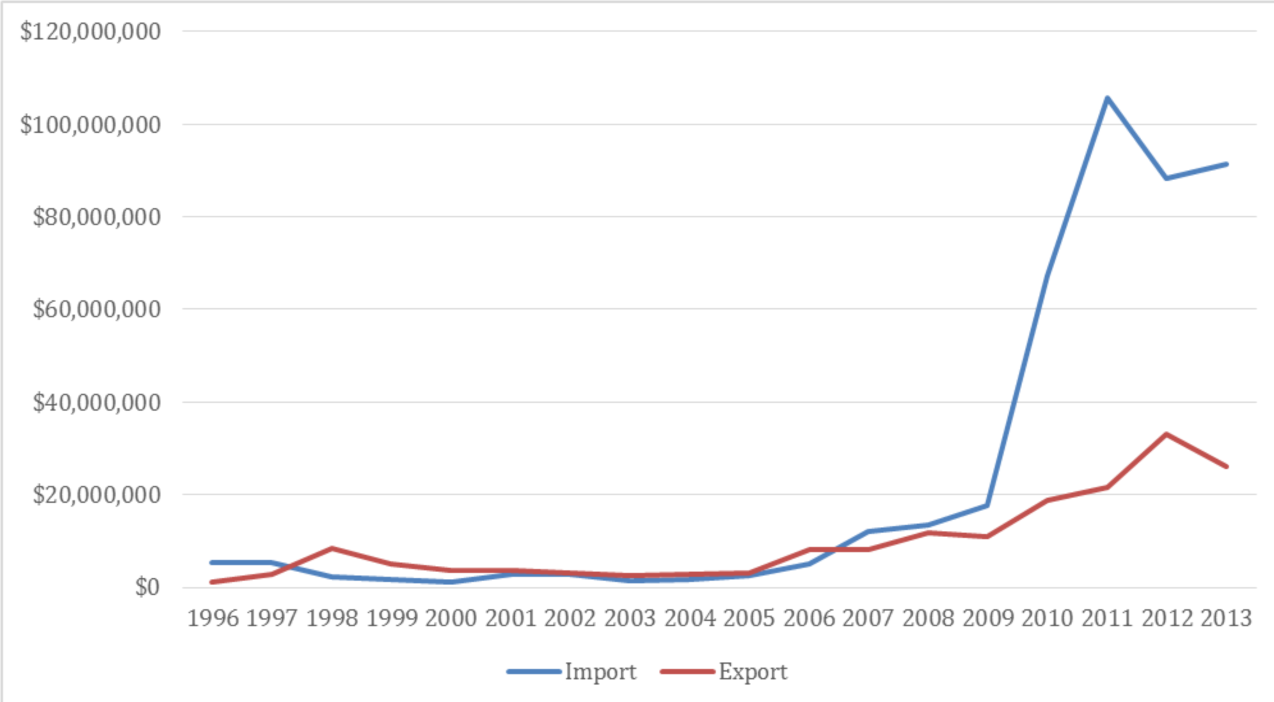

Figure 4-1: Canada's e-waste trade flow, 1996 - 2013

As this study shows from 1996 to 2013, the total e-waste trade flow in Canada was ($602,907,238). From this number, the import share of ($427,654,982) is almost 2.5 times that of the export, which was at ($175,252,256). There are numerous reasons that could explain this sudden expansion and answer the question of why a developed country moved from a net exporter to a net importer for electronic waste.

Reasons such as the following are contributing factors:

- Profitability
- E-waste transboundry regulation at the international level
- Technology advancement in waste treatment in the developed world
- Domestic regulations for collection and recycling of batteries
- Excess of domestic recycling capacity for specific batteries

- Pollution haven hypothesis effects

In the first case, one of the main reasons that could be the cause of this movement is the profitability of this action on a short term basis that provides a positive gain for the importer country's economy, especially countries with large areas. If this is the major reason for such a trade, then the cause can be the same as in developing countries that pursue profitability as a major reason for importing the hazardous wastes such as e-waste.

In contrast, being convinced by such a reason is difficult because in developed countries such as Canada, environmental regulations play an enormous role for preserving nature and health. Additionally, importing e-waste is in contradiction with the environmental regulations in most of the provinces. At the same time, such a profit in comparison to the economical size of countries such as Canada is not as large, therefore not providing enough of an incentive for countries to do such actions and risk the environment in the long run.

The other important issue is the role of international treaties such as the Basel convention. As in the past decade, the issue of e-waste trade flow has been discussed and highlighted as a dumping waste action done from developed to developing countries; therefore, the restrictions for transboundry movements are concentrated more on this issue and not the other way around or even inter-regional movements between developed countries.

In regards to the batteries specifically, the other regulations such as domestic transboundry movements for hazardous wastes in different countries can play an enormous role in the creation and magnitude direction of such trades as well. For example, in the trade case of the spent lead-acid batteries (SLABs) between Canada and the United States, the latter nation does not need a manifest for SLABs international movements. Additionally, it does not need SLAB exporters to acquire a recovery certificate from the recycling plant before shipment, something that is not the case in Canada [108].

It should be also noted that for the trade case of hazardous wastes between Canada and the United States, Canada has a bilateral trade agreement for these sorts of trades with the United States. This is due to this fact that the United States is not a participant in the Basel convention, and therefore does not need to follow its limitations whereas Canada, with a trade agreement, is able to trade with this country.

Based on the export data on the trade flows for SLABs from 2002 to 2011, export from the United States to Canada sharply increased from 2009 and in 2011 reaches its peak. The full trend graph of this trade movement can be found in APPENDIX B along with its import and export stage in 2011 in APPENDIX C [108].

The other aspect that can also be discussed is the technological advances that in the past decade were reached by some developed countries for enhancing their domestic recycling capabilities. This would pursue them to accept some external marginal e-waste from the other countries for economic reasons. With respect to the recycling of batteries, Canada is privileged to have a high recycling capacity in all types of batteries that are available in Canada and the United States [107].

Even with this important reason and despite all the technological advances that Canada has obtained from recycling processes in the 21st century; this reason is still not acceptable as the country still is not capable of recycling all its e-waste, including domestic batteries. Based on information from Environment Canada, more than 140,000 metric tonnes of electronic equipment are aggregated annually in Canadian landfills rather than being recycled [1]. Additionally concentrating on batteries, the statistics for the collection rate of the primary batteries for 2011 shows at best only one seventh of the available primary batteries have been collected [107].

The other logical reason that can be discussed is the role of domestic regulations for collection and recycling of batteries that are the major members of the UN Comtrade used database.

The main aspect of this reason can be due to the lack of mandatory recycling regulations in most provinces. As per the latest information, almost two-thirds of these provinces do not even have mandated programs for the recycling of batteries, as the program at the national level is run voluntarily by each province separately.

Another important reason that can explain this movement especially for the year 2007, is Environment Canada's claim for having the domestic excess recycling capacity of some specific sort of consumer batteries as well as the existing bilateral commercial arrangements between smelters and battery manufacturers in Canada and the United States. As based on this report, in 2007 three out of four Canadian consumer battery recycling facilities had an excess capacity of recycling for Lithium, Alkaline, Zinc Carbon and Cobalt bearing batteries. And five facilities for Lead smelters had almost twice the capacity from what they received for recycling for that year. The list of these recycling capacities can be found in APPENDIX D, APPENDIX E [109].

One interesting point about these recycling facilities is their locations as shown in APPENDIX F that are located near the United States border, which might not be coincidental.

The other plausible issue that might be the reason for the import expansions from 2008 onwards is the avoidance of environmental and health protection costs relevant to their stricter regulations in the United States. Specially in 2008 and 2012 by improving and tightening the ambient air and lead emission standards at battery recycling plants [108], caused export expansion from the United States to its trade partners including Canada. This tightness in the environmental regulation as Kellenberg mentioned earlier can lead to a waste haven atmosphere, which results in an increased export in movements from a country with high environmental regulations to lower ones [25].

In a general view on Canada's environmental performance for 2009 onwards, one key issue that should be taken into consideration is the massive downgrading of Canada's environmental performance index (EPI) during these years up to 2012. As the EPI shows, Canada stood in rank 12 in 2008, downgraded to rank 46 in 2010 and 37 in 2012 [110-112]. Additionally to this downgrading, it should be also noted that in the broader waste categories, Canada's municipal waste generation per capita fell from grade "C" in 1990 to grade "D" in 2002, which is lower than that of the United States [113]. Based on the recent international ranking in 2009, Canada stands at 17th out of the 17 OECD members ranked countries [113, 114].

These poor records on the environmental performance can also strengthen the impact of the pollution haven hypothesis for causing more imports than exports. On the other hand, it can be another proof to what was mentioned earlier by Kellenberg; for every percent fallen in the environmental regulations in one of the bilateral waste trade partners, the import of the wastes from the other foreign trade partner increases by 0.32% [25].

4.3.2 Canada e-waste Trade Network

After considering the numerous gaps between the values reported by Canada and its trade partners in the proxy used data, mapping Canada's e-waste trade flow has been implemented based on the largest values reported by each one of the importer or exporter parties for 1996 and 2013.

This issue opposes other similar research in this field such as Lepawsky' papers in 2010 [44] and 2014 [45]) which works on the same dataset. Other studies put in terms of the imported volume as the core data for their research because it is expected that countries tend to report their import more accurately than the exports. While in this study and by comparison the data reported by Canada and its trade partners, this issue was in contradiction.

For example, in Canada's e-waste trade flows case with the Unites states for most years, the imported value has been reported by the importer country less than the exporter value reported by the exporter country. This is not logical or reasonable because it was expected that equal numbers be produced or that this situation be reversed.

As shown in Figure 4-2, the majority of the Canadian e-waste import network in 2013, as is the same as the other map for 1996, is more toward the North American region, especially the United States that exported more than $95 million of the e-waste in 2013. In this year, Mexico with a far distance trade value away is the second exporter country in the region with slightly over $69,000 in export.

As it can be seen, Asian countries are the second largest exporter partners for this year to Canada, with Japan being the main exporter country at over $2.6 million, well above other countries in that region. For a better understanding of this distance, the second biggest exporter of the region after Japan is Vietnam with slightly over $126,000 export, therefore exhibiting a large gap between Japan and other nations.

Additionally as clearly shown by the map, Europe with a slightly lower total trade value than Asia, is the third region with the highest value of export to Canada. In this region, France with over $1.48 million trade is the leading exporter followed by Germany and Netherlands with each one trade of above $0.5 million in 2013.

Figure 4-2: Canada’s e-waste trade network, import 2013

Based on the latest data available and from what is shown in Figure 4-2, observations show that North America, Asia (especially Far East countries) and Europe are the main e-waste exporter trade partners to Canada in 2013.

This situation in the export of Canada to these countries for the same year is slightly different. As shown in Figure 4-3, the majority of this flow is the same as the import in 2013 toward the United States with about $26 million; however, as the export value shows, this number is almost 3.5 times less than the import of Canada from the United States which was about $95 million.

As Figure 4-3 shows, the other difference is at the region and the destination countries of the exports. Against the import, exports after the United States is more toward European countries especially Belgium with over $373,000. The Asian countries stepped in after Europe, ranking them in third place.

Figure 4-3: Canada's e-waste trade network, export 2013

By looking at Figure 4-3, one of the major points that must be taken into account is the absence of China, the biggest e-waste importer of the globe, among the importer countries. There is no report available for China that shows such a trade for 2013. This situation is almost the same for the other years export reports as well.

It was expected that Canada, as for other developed countries, has some degree of export to China, in which this issue was not observed vastly on the data reported especially from 2007 onwards. For most of these years, the opposite issue has been observed in a very small value scale.

In 2006, $228,800 has been reported by Canada which never repeated in the years before or after in such a value scale, which can empower the speculation of trades between countries without being reported or in other words some signs of illegal trades.

In order to obtain a better image of the e-waste trade movement among different years, the 1996 e-waste trade network has been mapped and shown to be comparable to the latest one in 2013. The

1996 network is the earliest network available in the UN Comtrade dataset whereas the 2013 network is the latest one.

Figure 4-4 below shows the e-waste import network of Canada in 1996. As the map shows, the major import flow is towards the United States, as is the same in 2013. The major difference is that the trade value in 1996 is much smaller than 2013 and is just about $4.7 million. The observation of lower numbers is expected due to technological revolutions and the larger role of electronics in the 21st century compared to older times as well as the smaller amount of e-waste produced in 1996.

The other issue that is of importance in the 1996 import map is the highlighted role of Asian countries with respect to their export to Canada which is similar as in the 2013 import map. Indonesia, with over $450,000 in exports after the United Sates is the second largest exporter in this year, followed by Japan with more than $247,000 as the second country in the Asian continent with the highest value of export.

European countries ranked third in overall in terms of value of trade in this year. Germany, with over $258,000 in exports, ranked as the highest exporter in this region and third overall at the global level. The second largest exporter in this region after Germany is the United Kingdom with $63,484 in export value.

Figure 4-4: Canada's e-waste trade network, import 1996

Furthermore, in the comparison of the exports between the 1996 and 2013 as shown in Figure 4-5, the export flow maps for 1996 and 2013 is mainly toward the United States, Europe and the Asian countries, with the difference of the lower value number compare to 2013.

In this year, the United States with over $1.25 million was the main trade partner and the importer, followed by United Kingdom with over $287,000 and India with more than $60,000. By comparison, the United States import in 2013 was almost 20 times larger than in 1996.

For this year one issue that needs to be taken into consideration is the limited available reported data, which is limited to five-exported destinations, half of that found in 2013.

Figure 4-5: Canada's e-waste trade network, export 1996

Generally speaking, from comparing the export and import maps from 2013 and 1996, one issue that can be easily recognized is the role of the three territories in the Canadian trade flow from these years. The North American, European and Asian countries were the main trade partners and the destination for the imports and the exports of the electronic wastes.

4.3.3 Main Trade Partners

This study investigated the Canadian e-waste trade partners in two different categories; first the main trade partners in respect to the average annual bilateral trade value in the last 18 years, and second the top trade partners with respect to the overall (import/export) number of trades reported by Canada for the same time period as the first category.

For the first category, Table 4-4 below shows the seven countries that are the main trade partners with Canada between 1996 and 2013 with over $35,000 average annual trade. As it is obvious, the United States with over $32.3 million average annual trade has the highest share in the list and therefore with a long distance is the main trade partner in the both import and the export among the other countries. This is followed by Japan with over $458,000 trade and France with over $141,000 trade as the second and the third ranked trade partners respectively.

Table 4-3: Canada’s main trade partners with respect to the average annual trade value, from 1996 to 2013.

Rank	Trade Partner	Average Annual Trade Value, Reported by Canada ($U.S)
1	United States	32,342,379
2	Japan	458,866
4	France	141,692
3	Austria	121,177
5	Netherlands	80,320
6	China	54,641
7	United Kingdom	36,272

This situation is slightly different with respect to the overall number of trades reported by Canada. As shown in Table 4-4, the United States with 36 trades during the past 18 years has been the only country with the full number of trades reported by Canada for all years, followed by China with 21 and Japan with 20. This means that either in the other years no trade data has been reported by Canada or that there was no trade occurred, or occurred and not been reported.

This issue will be discussed and analyzed more in the gap analysis section, but as the observations on the partner countries trade reports shows, a lot of trades have been reported by the trade partner countries in different years by different countries, that they never been reported by Canada, despite the fact that the inverse has been shown as well.

The full list of trade partners ranked by the overall number of trades reported by Canada is available in the APPENDIX G. As it can be seen there, this study divided the second category into three sub categories. Primarily, countries who have more than ten overall number of trades with Canada, secondly to those that have more than two or less than ten number of overall trades and lastly trade partners who have only one or two overall trades with Canada in the last 18 years.

Table 4-4: The main trade partners with respect to the overall number of trades reported by Canada, from 1996 to 2013.

Rank	Trade Partner	Number of Overall Trades Reported by Canada
1	United States	36
2	China	21
3	Japan	20
4	United Kingdom	19
5	Mexico	17
6	Germany	17
7	France	15

4.4 Illicit Trades

4.4.1 Reported Data from Different Countries

By observing and analyzing the data from the UN Comtrade database, one important issue that can be vastly surveyed and requires to be carefully considered is the fact that there is a large gap in most reports as provided for different years between the numbers that the imported and the exported countries.

It is expected that the countries would not tend to have enough interest for recording and reporting accurate export numbers compared to imports, especially for those who signed the international treaties such as Basel convention due to international boundaries for transboundary movements of hazardous wastes including electronic waste within the regions and the countries. But despite this fact, the UN Comtrade dataset HS code 854810 in some cases shows that can sway in the opposite direction. The importing countries have even reported numbers of lesser value than the exporting countries for the same report year.

4.4.2 Gap Analysis

As was mentioned and discussed earlier in this chapter during the analysis of the data, the big gaps observed in the reported data submitted by Canada and its trade partners to the UN Comtrade database.

For better understanding of these gaps in different years, Figure 4-6 has been drawn based on the comparison of the import data reported by Canada and the exported data reported by the other trade partners in different years.

As it can be expected in the normal situation and by considering the exchange rate, the reported data by the importer and the exporter country for a specific year should be the same or similar. But as this study shows, for some countries this issue is not valid and the importer and the exporter countries have reported the data differently.

The top nine of these countries have been considered in Figure 4-6 and, as it can be clearly seen for most years in the exported data reported by the United States and the imported data reported by

Canada, there are large gaps in the data reported by each of these countries. This difference just in 2011 is up to $9 million.

By looking more precisely at Figure 4-6, the countries that have the biggest trade value gaps in their export reports with respect to the import reports for Canada are the United States, followed by Japan, Germany and the United Kingdom. As it can be seen for most of these years, the United States, Germany and the United Kingdom reports contain greater export values than the recorded Canadian import value.

This situation after 2010 is valid for Japan as well, but in the last three years of the reports, this issue is inverted as Canada reported more imports than Japan's exports.

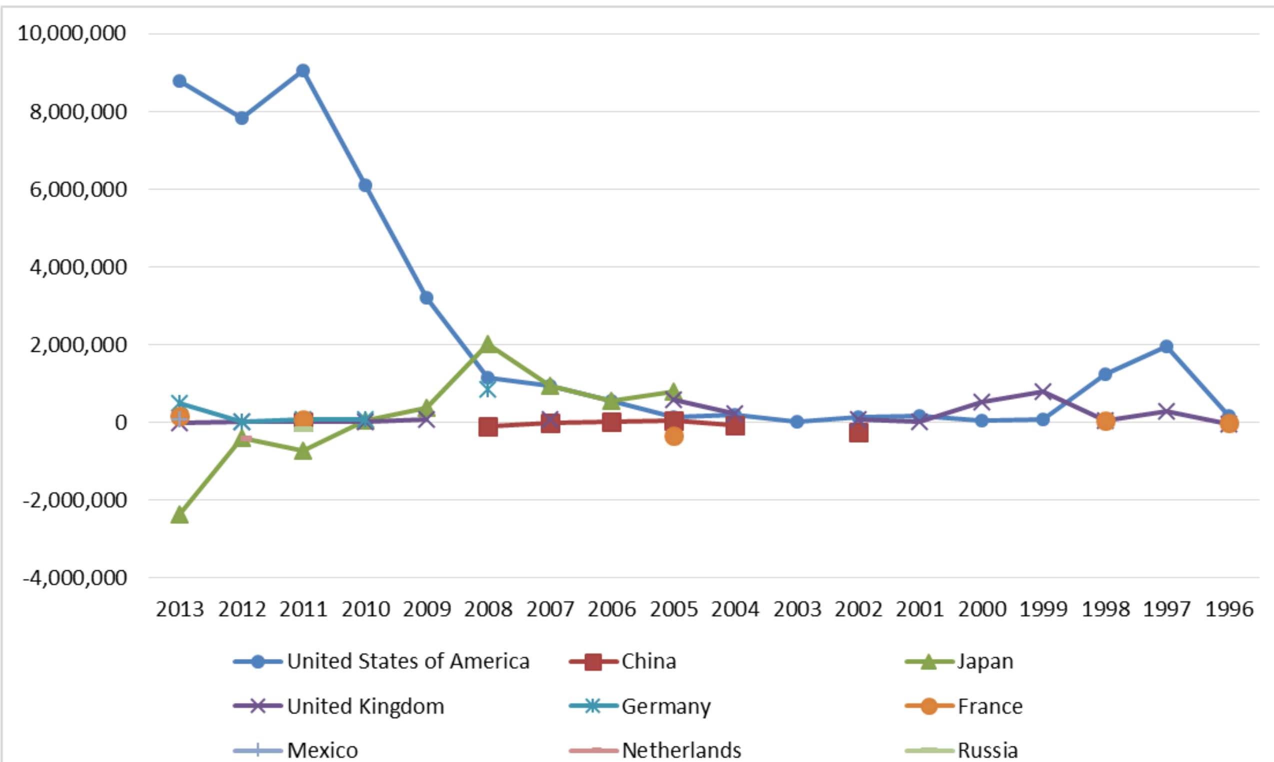

Figure 4-6: Canadian imports reported differences with other countries exports reported.

In confrontation with the Canadian import reports versus the other countries' export reports, Figure 4-7 illustrates the opposite situation with concentration on the Canadian export reports differences with the other countries import reports.

As shown in Figure 4-7, this situation for the Canada's export reports is very different, as a smaller number of differences found in the trade reports between trade parties. This could be due to more accurate reporting in Canadian exports or that there are a fewer number of trades between the trading parties, or even due to the lack of reported data availability on the export side of Canada and the import side of the other countries.

As it can be seen, the majority of these data gaps are between the export reports of Canada with the import reports of the United States. With the exception of 2013 where in this year Canada reported about $1 million more in export, the United States reported more imports than the Canada's export in other years.

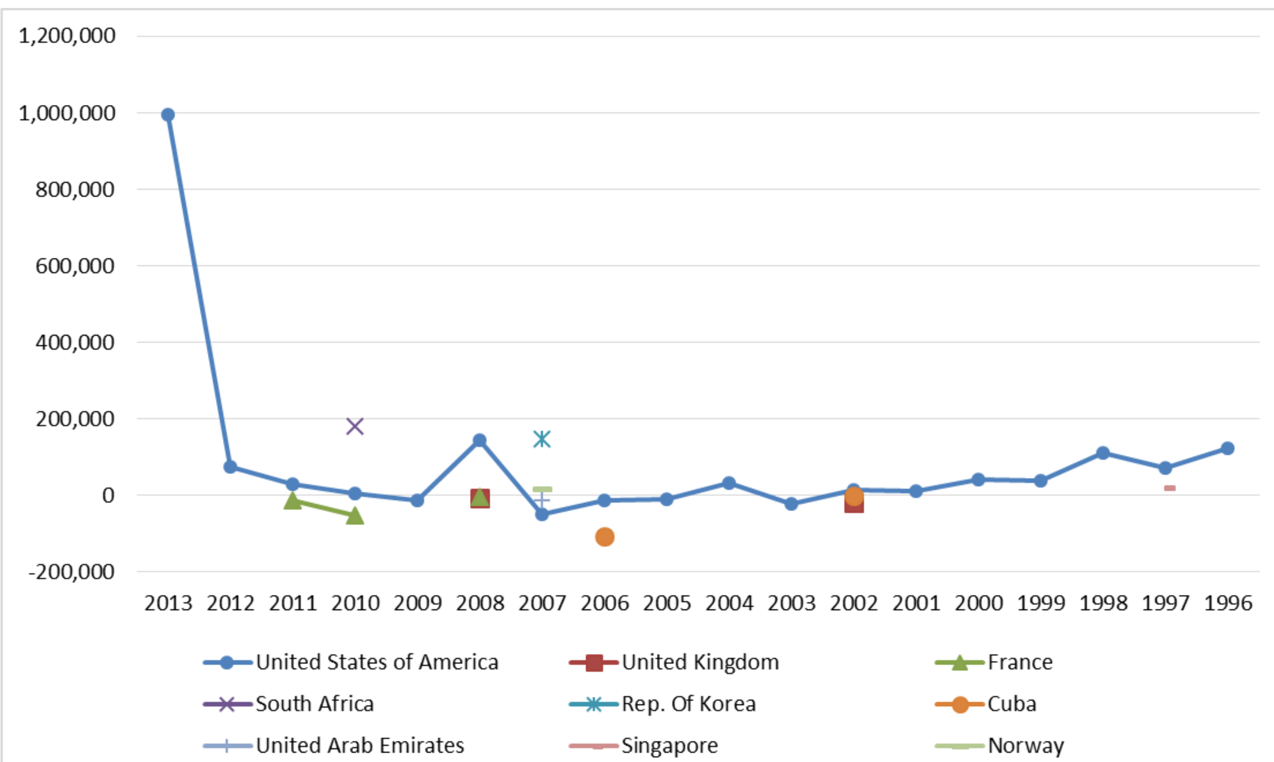

Figure 4-7: Canadian exports reported differences with other countries imports reported.

For a better understanding of these gaps, the difference from both parties' reports on their average also taken into consideration. This calculation can help evaluate the degree to which differences between both countries' reports are shown in different years.

As it can be seen in Figure 4-8, the degree of gaps between the countries is disparate and is between 2 and -2. In other words, the countries that stand near the number 2 are those that reported the largest export gaps compared to the import report of Canada; the rest that are near number -2 are those who reported the least value in their export report compared to the same year import reports of Canada.

Also in this graph, some countries do not have the biggest degree of gaps as shown in Figure 4-6. As an example and in the case of United States, despite the fact that Figure 4-6 shows the biggest differences of reporting between 2008 and 2013, Figure 4-8 reveals different facts.

Although the gaps are big in terms of numerical value, the degree of differences are not as large as expected. In terms of comparison with respect to the 1997 and 1998 repots, the degree of gaps are near zero, since in these years the United States reported a higher amount of export by two and three times respectively than the import recorded by the Canada's report.

As Figure 4-8 reveals, the United Kingdom, Germany and Japan are the countries with the highest gaps of export reports with the import recorded by Canada for most of the reports years. In front, China in report years of 2007 and 2008 and Japan in 2011 to 2013 are countries with the least reported values of export compared to the highest value of import reported by Canada.

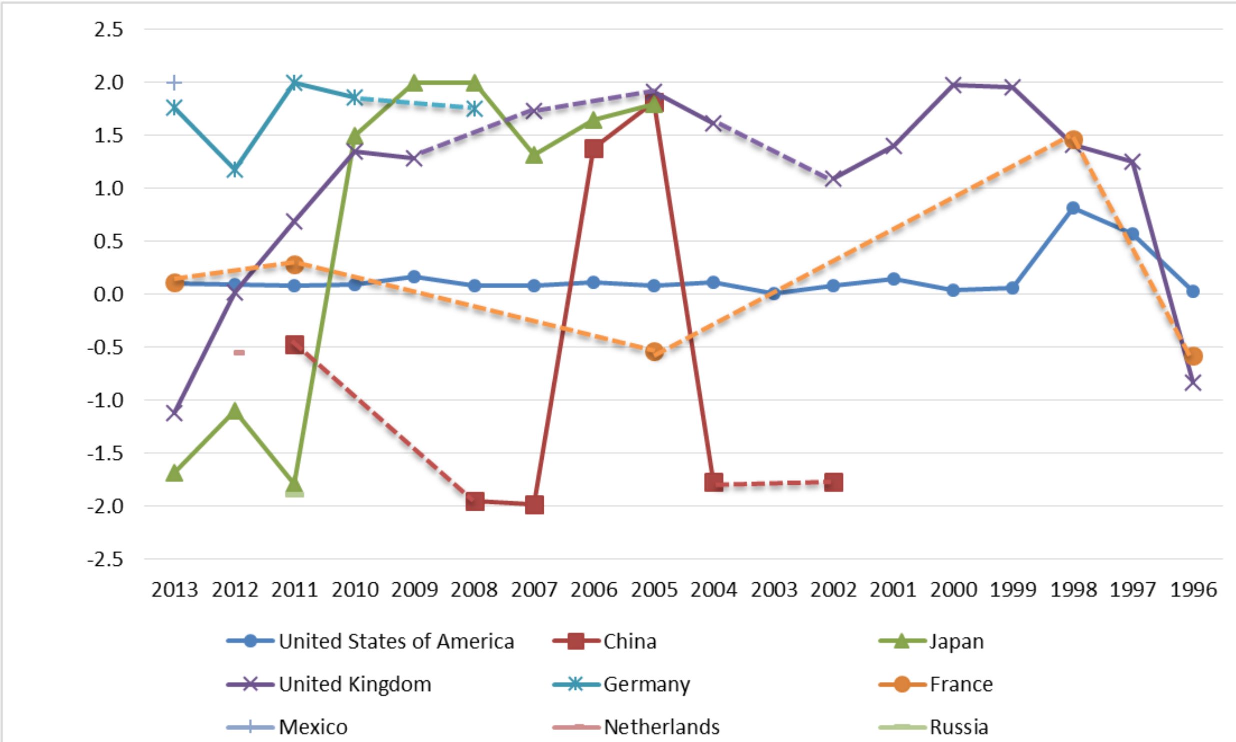

Figure 4-8: Canadian imports reported differences with other countries exports reported divided on the average of both parties report's numbers.

This fluctuation on the other side of the reports has been observed as well. As it can be seen in Figure 4-9, the degree of gaps between the export reports of Canada and the import reports of the United States is almost a steady line. The United States no longer represents the country with the biggest gap, the same as shown in Figure 4-7.

This issue is due to the fact that although the gap between these two countries goes up to $1 million in 2013; however, in comparison to the total value of the trade between the two parties, this difference is small and is not as much as in other countries.

In Figure 4-9, South Africa and Norway are two countries whose import reported gaps with respect to the export reported in Canada are very close to number 2 in the years 2010 and 2007. These are the countries that reported the biggest degree of import in comparison to the least degree of export value reported by the Canadian side.

This situation is in contrast to the two countries of Cuba and the United Kingdom, whose degree of gaps in the years of 2006 and 2002 are very close to -2. These countries reported the least value of import in comparison to the export reported by Canada in those years.

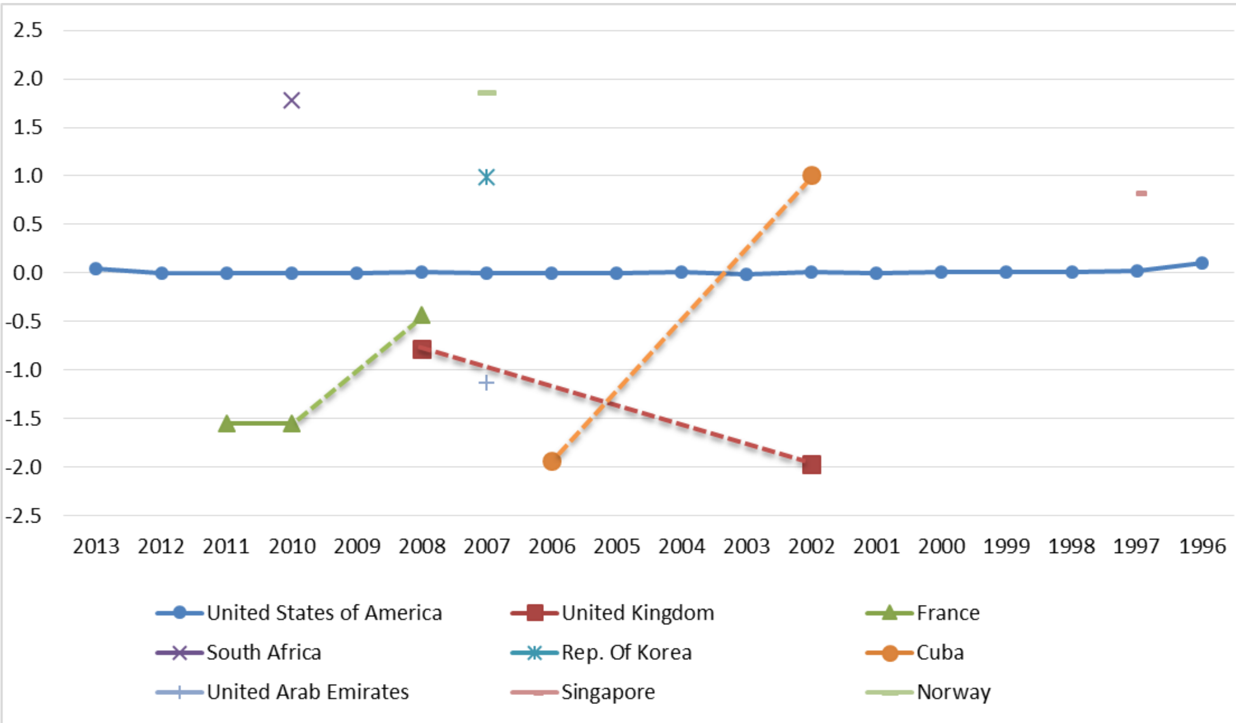

Figure 4-9: Canadian exports reported differences with other countries imports reported divided on the average of both parties report's numbers.

There are lots of reasons that could explain the discovered gaps between the reported data by Canada and its trade partners. This study will go through some of these causes. The top potential reasons have been listed as follows:

- Statistical error
- Mistake on purpose (due to domestic or International regulation boundaries such as the Basel convention)
- Bureaucracy and corruption

- Illegal trade

As it can be expected, the statistical error in any sort of mass data reporting is inescapable; however, the issue that matters the most here is the degree of these errors.

In the case of UN Comtrade database, the gap between the countries' reports cannot have simply just occurred due to some accidental errors on the reporting data since the observed gaps are not limited to a few countries and consist of a large majority of most of the reported countries. Hence, the next potential issue that might be the reason of this occurrence can be discussed which is mistake by purpose.

There are plenty of reasons that can encourage the countries involved in such a trade to report the wrong trade data. The most important of them is the international conventions and their regulation boundaries that banned the trade and export of such a hazardous waste between the developed and the developing countries. Ignoring such regulations for the members of such conventions can be penalized and have negative points for the involved parties.

This issue can also be valid for the domestic regulations of countries such as Canada as well. As in this case, each Canadian province manages e-waste and waste of batteries regulation independently. Therefore, one province regulation is not necessarily the same as the other one, and each one of them reports its own data separately from the others. In general, insuring all these reports are accurate is a difficult task as these variations in reporting can lead to statistical errors as well.

On the other hand, this variation in reporting can increase the chance of error via bureaucratic and corruptive means between the involved parties and organizations within and outside of Canada. This may also apply among other trading countries as well since not all countries have the same e-waste, battery regulations, and follows the same collection and reporting procedures.

Furthermore, at the top of all-potential reasons for the observed gaps on the database is false reporting by the purpose of illegal trades among the involved parties, since the importer and the exporter parties have their own benefits in such a trade.

One issue that this study has faced and discovered by its research on the recycling sites in Canada is the existence of the unofficial recycling plants. For example, in the province of Ontario privatization exists and does not necessarily work on reporting to government agencies directly, which would raise suspicion of illicit trades by such recycling plants for the aim of profitability. It should be noted that this issue is not proven and is just a supposition which needs to be addressed and further evaluated in depth in a separate study.

CHAPTER 5 FUTURE TRENDS

5.1 Time Series Model

In regards to the third defined objective of the thesis, creating a future picture of the e-waste in Canada is possible based on the condition imposed on the current available data. This chapter fulfills this objective while trying to establish a platform for comparing the current and the future e-waste scenarios. This might help the country to have a better future vision for confrontation with this issue as opposed to threatening nature and the environment.

As the UN Comtrade e-waste trade data for Canada is related to time and is available from 1996 to 2013, it is therefore possible to forecast the future trend of the trade flows by means of a time series model for a short period of time over the next five years. Therefore, in order to better underline these trends, the import and export forecasting models have been calculated in this section.

At first, several time series models have been evaluated by the Minitab software for all trade data. Additionally, the double exponential and exponential growth methods have been chosen among others which best suits these analyses.

For a more accurate analysis of the results, both models have been implemented on both the imports and the exports data continuously whereas the outputs have been compared together in each section separately.

Due to the fact that the predictions are not absolute because of the different external factors that can effects the results, it should be mentioned that the results can be effective and useful for the future if everything stays the same. Issues such as change of regulations and the future environmental situation of Canada among its trade partners can affect the forecasts.

5.1.1 Double Exponential Method for Import

The concept of double exponential smoothing involves the smoothing of data by Holt (and Brown under exceptional circumstances) so that short-term forecasts are provided. This process works effectively when a trend is noted; however, it additionally serves as a smoothing method for all potential scenarios. The level and trend are the two components in which calculations for dynamic estimates are done [115].

Model Equation:

Double exponential smoothing uses a level and a trend component for each period. It uses two weights, also known as smoothing parameters, in order to update each of the respective components per period. The equations are [115]:

$$L_t = \alpha\ Y_t + (1 - \alpha)\ [L_{t-1} + T_{t-1}]$$

$$T_t = \gamma\ [L_t - L_{t-1}] + (1 - \gamma)\ T_{t-1}$$

$$\hat{Y}_t = L_{t-1} + T_{t-1}$$

$$Resi_t = Y_t - \hat{Y}_t$$

Where:

- "…*L_t is the level at time t, α is the weight for the level*
- *T_t is the trend at time t, γ is the weight for the trend*
- *Y_t is the data value at time t, and $\hat{Y}_t$ is the fitted value, or one-step-ahead forecast, at time t*
- *Resi is the residual value at time t*…" [115].

Figure 5-1 shows the smoothing plot for import in the double exponential method. As Figure 5-1 shows, the actual numbers have been plotted by the blue line, and the model fits can be seen next to it by the red line color.

The forecasted amount is shown by the green line and by the 95% prediction interval bands between the two purple lines for the years 2014 to 2018. And as it can be seen, the actual data chart and the fitted chart are almost similar, in which, this shows the double exponential method is an appropriate model for the import data.

Due to the limited time period availability of the actual data, the analysis can only be done for a short period of time. As the results in the fitted chart show, the predictions are in a growing trend which are intensively related to the last year's observations.

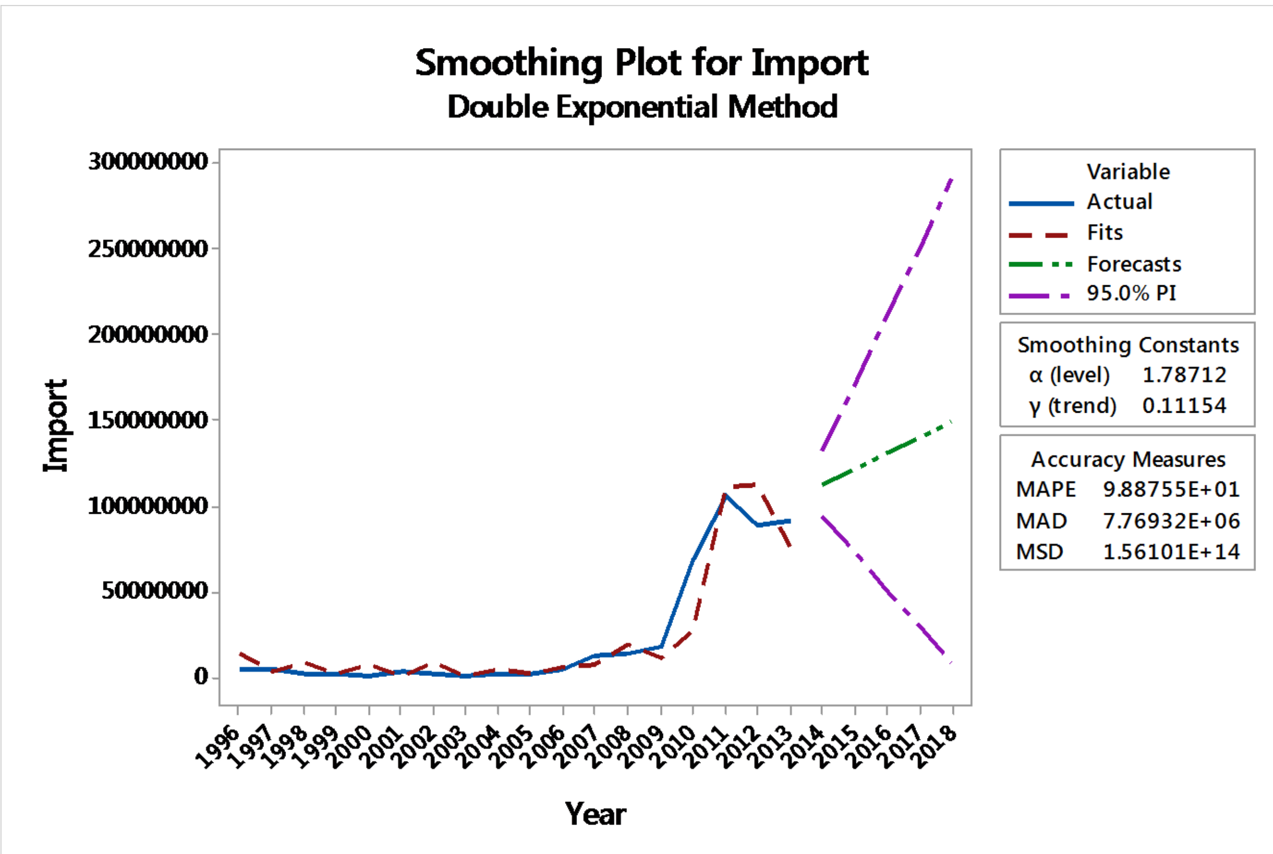

Figure 5-1: Fits and Forecasts using the double exponential method for import.

Table 5-1 shows the summary of the results and the amount calculated for the Fits, Residuals, Trend Components and the Level Components.

Table 5-1: Summary and results of the double exponential method for import data.

Year	Import (Y_t)	Level (L_t)	Trend (T_t)	FITS1 ($\hat{Y}_t$)	RESI
1996	5223151	-1490743	4898040	13752824	-8529673
1997	5261240	6720519	2605272	3407297	1853943
1998	2285854	-3255436	5646270	9325791	-7039937
1999	1757894	1259693	5520098	2390834	-632940
2000	1165822	-3253057	4400990	6779791	-5613969
2001	2914598	4305179	4753163	1147933	1766665
2002	2742046	-2229650	3494051	9058342	-6316296
2003	1314894	1354638	3504117	1264401	50492.91
2004	1680500	-821175	2870553	4858755	-3178255
2005	2501396	2857189	2960660	2049378	452018
2006	4928027	4227628	2783279	5817849	-889822
2007	12053710	16023011	3788529	7010908	5042802
2008	13486040	8507099	2527582	19811540	-6325500
2009	17599578	22766953	3836251	11034681	6564897
2010	67376018	99469202	11964042	26603204	40772814
2011	1.06E+08	1.01E+08	10806557	1.11E+08	-5806486
2012	88331751	69809863	6115778	1.12E+08	-2.4E+07
2013	91405705	1.04E+08	9201626	75925641	15480064

Smoothing Constants:	α (level) =1.78712
	γ (trend) = 0.11154

Table 5-2 shows the accuracy measurements of the prediction over the next 5 years.

Table 5-2: Accuracy measurements in double exponential method for import.

MAPE	9.88755E+01
MAD	7.76932E+06
MSD	1.56101E+14

Table 5-3 shows the volume forecasted for the years 2014 to 2018.

Table 5-3: Forecast using the double exponential method for import.

Year	**Forecast ($U.S)**	**Lower IP ($U.S)**	**Upper IP ($U.S)**
2014	112792032	131826511	93757553
2015	121993659	171531327	72455991
2016	131195285	211287007	51103563
2017	140396911	251051425	29742398
2018	149598538	290818908	8378168.1

The blue line in Figure 5-2 shows the total Canadian import between 1996 and 2013 and the red line shows the forecasted trend for the following years of 2014 to 2018.

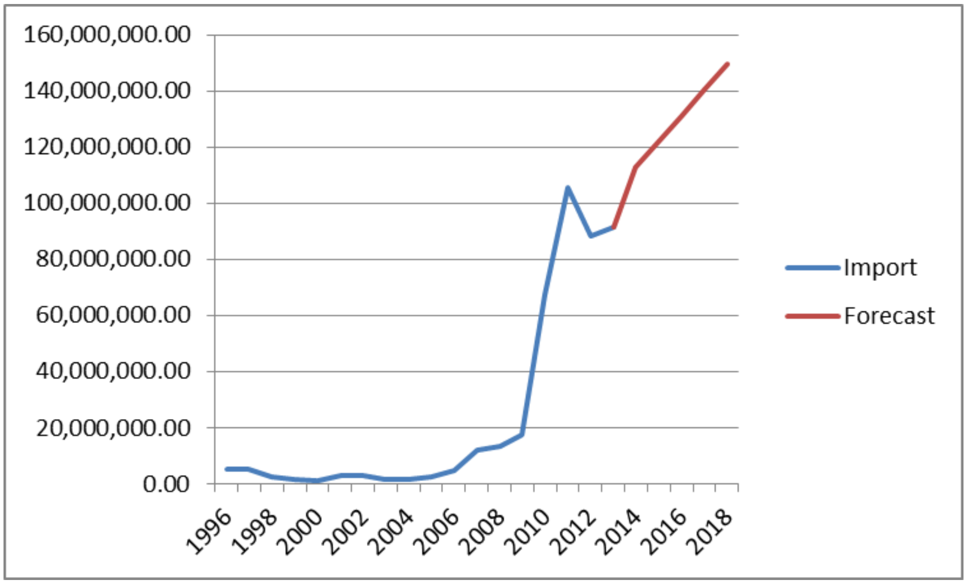

Figure 5-2: Time series plot of double exponential method for import data with forecasts.

Based on the forecasted amount by the double exponential method, the import of Canada in 2014 compared to 2013 will increase sharply, but this expansion in following years will continue with a less steeper slope.

5.1.2 Exponential Growth Trend Model for Import

As Minitab defines it: "…*The exponential growth trend model accounts for exponential growth or decay*..." [115]. The model is [115]:

$$Y_T = \beta_0 \times \beta_1^t + e_t$$

In this equation, the average change exhibited from time period to time period is shown by β1 [115].

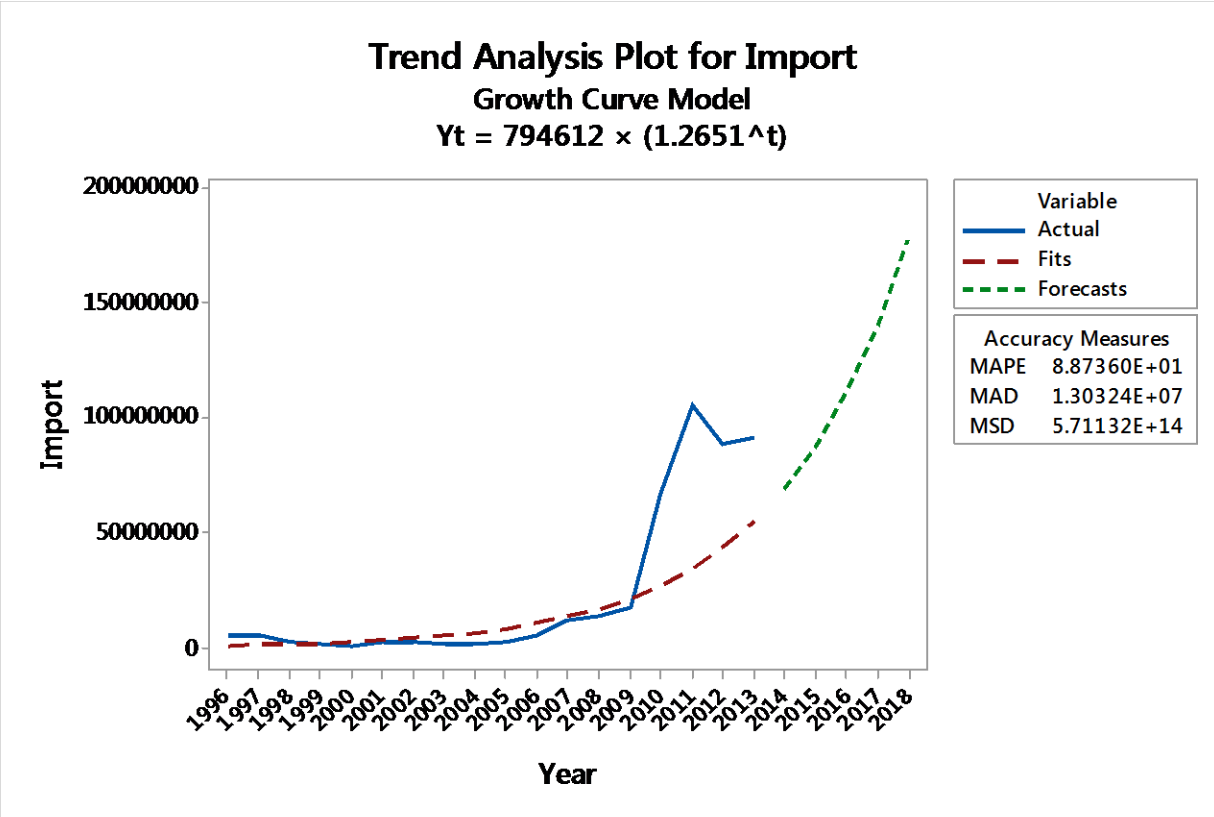

Figure 5-3: Fits and Forecasts using the exponential growth trend model for import.

By comparing the Actual amounts (blue line) with the amounts shown by the Fits trend (red line) in the exponential growth trend model in Figure 5-3, it can be said that up until 2009 there is an appropriate Fits for the data in this model; however, from this year onwards the growth trend compared to the Actual data decreases.

The mathematical equation for this model is as follows:

$$Import_T = 794612 \times 1.2651^t$$

Table 5-4 shows the comparison results of the calculated Fits with the Actual amounts.

Table 5-4: Summary and results table of exponential growth trend model for import data.

Year	Import	FITS	RESI
1996	5223151	1005227	4217924
1997	5261240	1271666	3989574
1998	2285854	1608725	677129
1999	1757894	2035123	-277229
2000	1165822	2574539	-1408717
2001	2914598	3256930	-342332
2002	2742046	4120190	-1378144
2003	1314894	5212260	-3897366
2004	1680500	6593788	-4913288
2005	2501396	8341494	-5840098
2006	4928027	10552435	-5624408
2007	12053710	13349394	-1295684
2008	13486040	16887696	-3401656
2009	17599578	21363837	-3764259
2010	67376018	27026395	40349623
2011	1.06E+08	34189833	71436924
2012	88331751	43251965	45079786
2013	91405705	54716046	36689659

Table 5-5 shows the accuracy measurements of the prediction for the next 5 years.

Table 5-5: Accuracy measurements in exponential growth trend model for import.

MAPE	8.87360E+01
MAD	1.30324E+07
MSD	5.71132E+14

Table 5-6 shows the volume forecasted for the years 2014 to 2018.

Table 5-6: Forecast using the exponential growth trend model for import.

Year	**Forecast ($U.S)**
2014	69218720
2015	87565377
2016	110774878
2017	140136137
2018	177279697

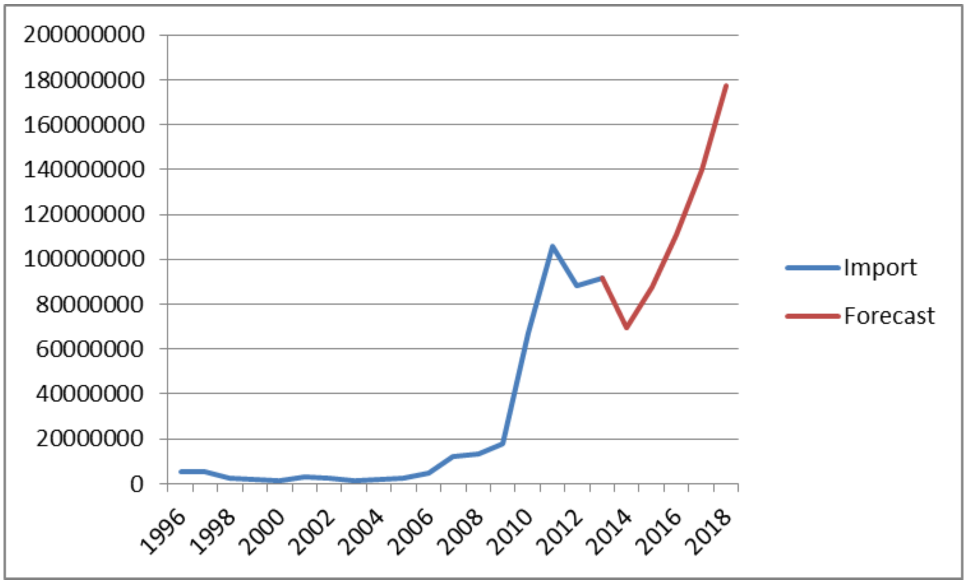

Figure 5-4: Time series plot of exponential growth trend model for import data with forecasts.

Based on the predicted amounts by use of the exponential growth trend model as shown in Figure 5-4, the amount of Canadian import in 2014 compared to 2013 will decrease, but in following years will continue to rise.

5.1.3 Import Model Comparison

The two methods have been compared in order to select the best model for the import, based on the two criteria for accuracy and error.

Table 5-7 shows the accuracy parameters of the two models:

Table 5-7: Accuracy measurement comparison for import models.

Accuracy Measures	Double Exponential Method	Exponential Growth Trend
MAPE	9.88755E+01	8.87360E+01
MAD	7.76932E+06	1.30324E+07
MSD	1.56101E+14	5.71132E+14

Although the MAPE measure in the exponential growth model is less than the Double Exponential Method, the other two criteria are larger in magnitude as shown by the table above. Therefore, the Double Exponential Method can be considered as a more appropriate model for imports.

For more information regarding the accuracy measures formula and definitions, please see APPENDIX H, APPENDIX I, APPENDIX J.

Table 5-8 shows the error of the model for each year.

Table 5-8: Error measurement comparison for import models.

Year	Import	RESI Double Exponential Method	RESI Exponential Growth Trend
1996	5223151	-8529673	4217924
1997	5261240	1853943	3989574
1998	2285854	-7039937	677129
1999	1757894	-632940	-277229
2000	1165822	-5613969	-1408717
2001	2914598	1766665	-342332
2002	2742046	-6316296	-1378144
2003	1314894	50492.91	-3897366
2004	1680500	-3178255	-4913288
2005	2501396	452018	-5840098
2006	4928027	-889822	-5624408
2007	12053710	5042802	-1295684
2008	13486040	-6325500	-3401656
2009	17599578	6564897	-3764259
2010	67376018	40772814	40349623
2011	1.06E+08	-5806486	71436924
2012	88331751	-2.4E+07	45079786
2013	91405705	15480064	36689659

Figure 5-5, the residual plot shows the residuals of the two models. Their patterns are random without any structure, indicating a good fit for these models. Based on the all results, it can be concluded, therefore, that the double exponential model is a more appropriate model for the import data series due to lower MSD and MAD measures that indicate a higher level of accuracy.

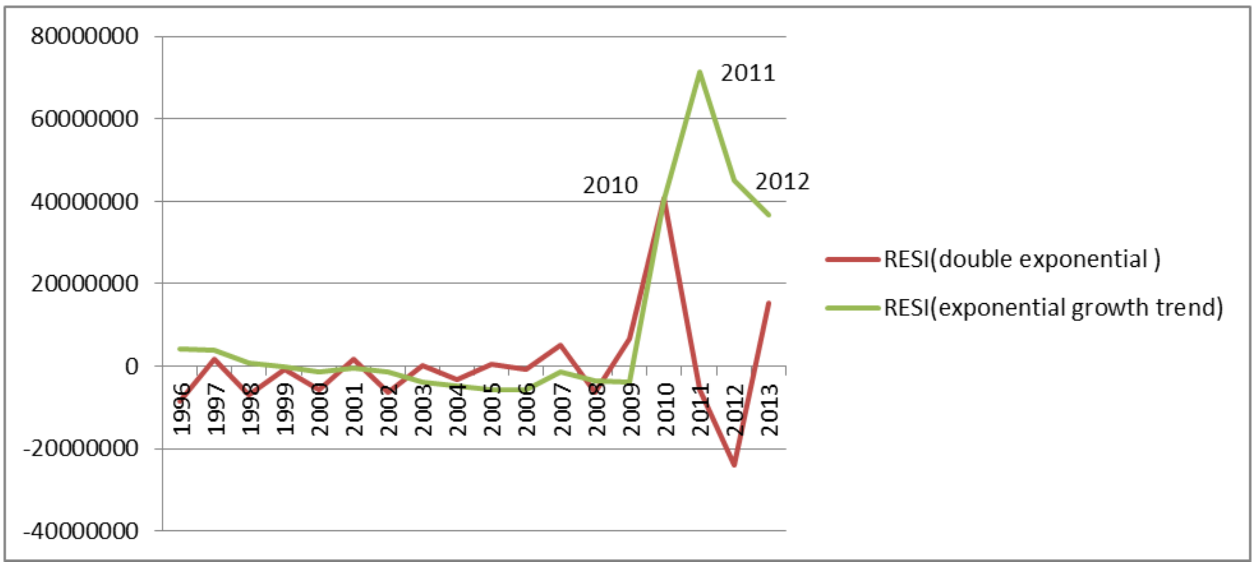

Figure 5-5: Residual series of double exponential method and exponential growth trend model for import data.

5.1.4 Double Exponential Method for Export

Generally speaking, the export data shows an increasing trend omitting the seasonal component. It seems reasonable to state that this series positively changes exponentially over period of time. As a result, two appropriate models can be considered for export data followed by a comparison of the two. First, the double exponential model will be considered.

Figure 5-6 shows the trend plot of the original data, the Fitted trend line and the Forecasts in this method. It also displays the Fitted trend equation and the three measures of accuracy for determining the accuracy of the fitted values: MAPE, MAD, and MSD. From Figure 5-6 in general it can be said that the double exponential method appears to fit well to the overall trend.

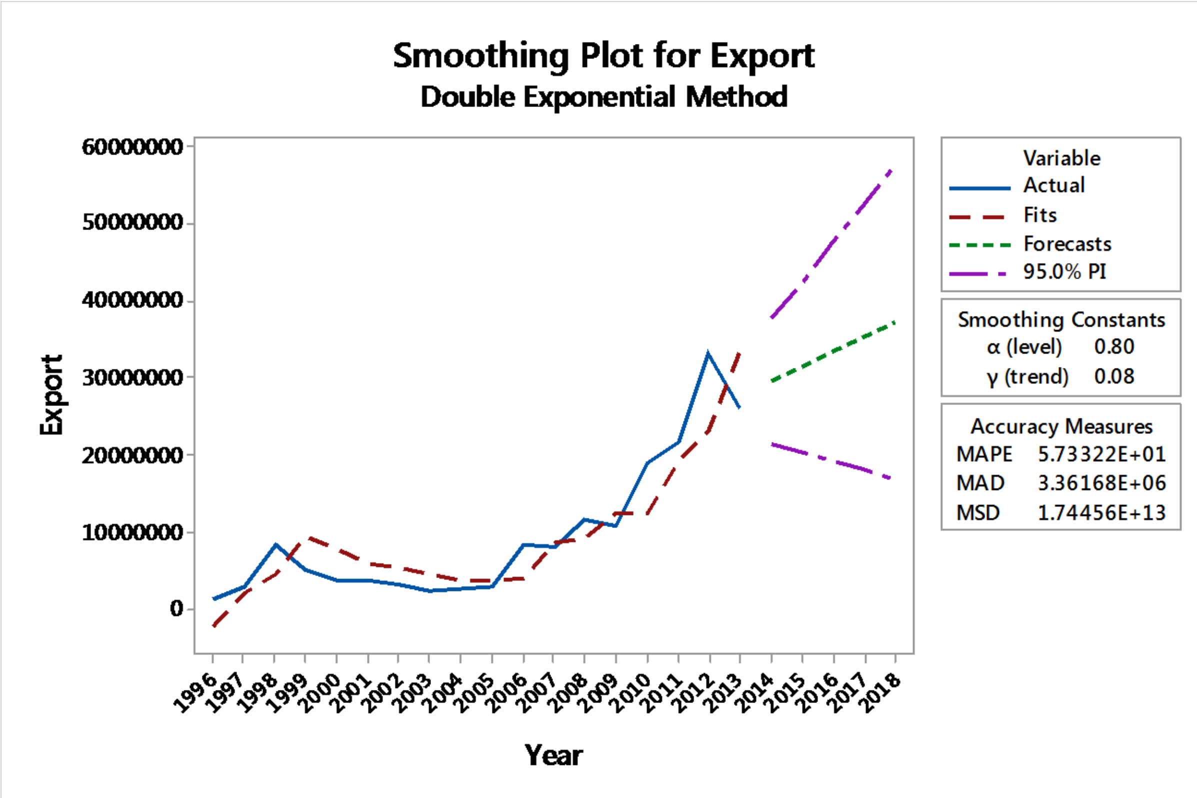

Figure 5-6: Fits and Forecasts using the Double exponential method for export.

Table 5-9 reveals the summary of the results and the amount calculated for the Fits, Residuals, Trend Components and the Level Components of the export data.

Table 5-9: Summary and results of the double exponential method for export data.

Year	Export (Y_t)	Level (L_t)	Trend (T_t)	FITS1 ($\hat{Y}_t$)	RESI
1996	1252613	557620.8	1629290	-2222348	3474961
1997	2953851	2800463	1678374	2186911	766940.4
1998	8391083	7608634	1928758	4478837	3912246
1999	5190975	6060258	1650587	9537391	-4346416
2000	3730299	4526408	1395832	7710845	-3980546
2001	3720131	4160553	1254897	5922240	-2202109
2002	3067220	3536866	1104610	5415450	-2348230
2003	2420320	2864551	962456.3	4641476	-2221156
2004	2729094	2948677	892189.9	3827008	-1097914
2005	3039672	3199911	840913.4	3840867	-801195
2006	8240493	7400559	1109692	4040824	4199669
2007	8027278	8123873	1078782	8510251	-482973
2008	11661345	11169607	1236138	9202655	2458690
2009	10895071	11197206	1139455	12405745	-1510674
2010	18864607	17559018	1557244	12336661	6527946
2011	21727549	21205291	1724366	19116261	2611288
2012	33168575	31120791	2379657	22929657	10238918
2013	26172077	27637751	1910641	33500448	-7328371
Smoothing Constants:		α (level) = 0.80			
		γ (trend) = 0.08			

Table 5-10 shows the accuracy measurements of the prediction for the next 5 years.

Table 5-10: Accuracy measurements using the double exponential method for export.

MAPE	5.73322E+01
MAD	3.36168E+06
MSD	1.74456E+13

Table 5-11 shows the volume forecasted for the years 2014 to 2018.

Table 5-11: Forecast using the double exponential method for export.

Year	**Forecast ($U.S)**	**Lower IP ($U.S)**	**Upper IP ($U.S)**
2014	29548392	37784357	21312427
2015	31459033	42508740	20409326
2016	33369674	47443297	19296051
2017	35280315	52477515	18083115
2018	37190956	57565608	16816303

Based on the predicted values of the double exponential method and as shown in Figure 20, the exports in 2014 compared to the previous year will increase. Additionally, this trend will continue to rise in future years as well.

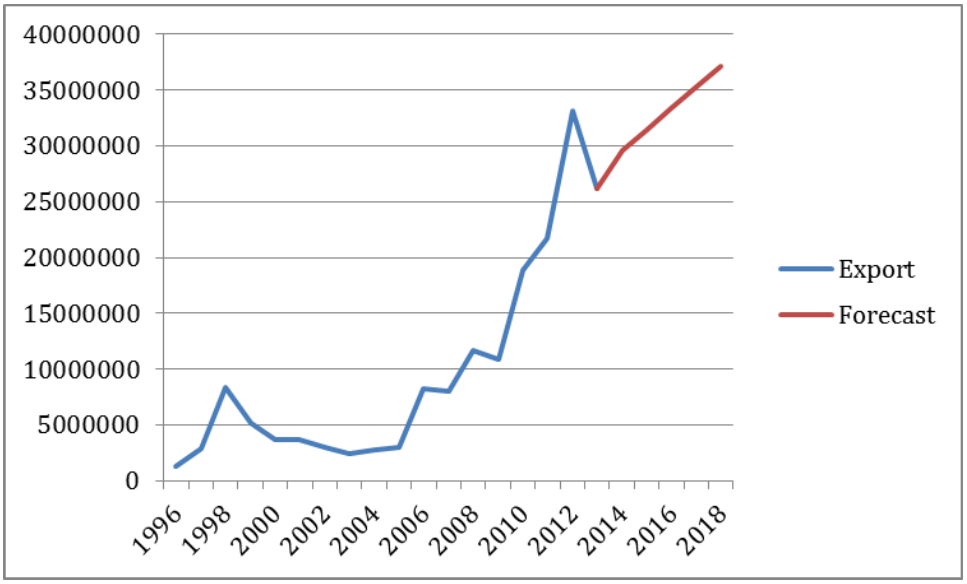

Figure 5-7: Time series plot of double exponential method for export data with forecasts.

5.1.5 Exponential Growth Trend Model for Export

As it can be observed in Figure 5-8, the exponential growth model has been able to identify the trend of the actual data.

The mathematical equations of the model are as follows:

$$Export_T = 1631754 \times 1.1563^t$$

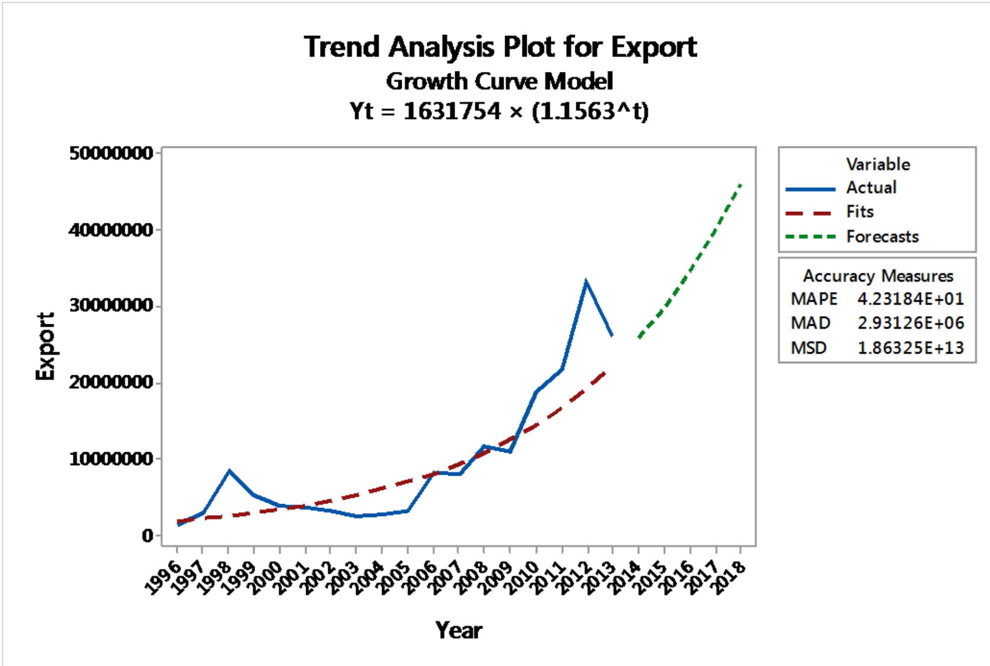

Figure 5-8: Fits and Forecasts using the exponential growth trend model for export.

Table 5-12 below shows the results comparing the calculated Fits with the Actual amounts.

Table 5-12: Summary and results table of exponential growth trend model for export data.

Year	Export	FITS	RESI
1996	1252613	1886846	-634233
1997	2953851	2181816	772035
1998	8391083	2522899	5868184
1999	5190975	2917303	2273672
2000	3730299	3373365	356934
2001	3720131	3900723	-180592
2002	3067220	4510522	-1443302
2003	2420320	5215651	-2795331
2004	2729094	6031013	-3301919
2005	3039672	6973841	-3934169
2006	8240493	8064060	176433
2007	8027278	9324714	-1297436
2008	11661345	10782445	878900
2009	10895071	12468063	-1572992
2010	18864607	14417193	4447414
2011	21727549	16671031	5056518
2012	33168575	19277211	13891364
2013	26172077	22290815	3881262

Table 5-13 shows the accuracy measurements of the prediction for the next 5 years.

Table 5-13: Accuracy measurements in exponential growth trend method for export.

MAPE	4.23184E+01
MAD	2.93126E+06
MSD	1.86325E+13

Table 5-14 shows the volume forecasted from 2014 to 2018.

Table 5-14: Forecast of exponential growth trend model for export.

Year	**Forecast ($U.S)**
2014	25775535
2015	29805020
2016	34464435
2017	39852255
2018	46082352

As shown in Figure 5-9, the exponential growth trend model predicts a slight decrease in the export of 2014 compared to 2013, but this issue will be reversed in the years after and will start rising again.

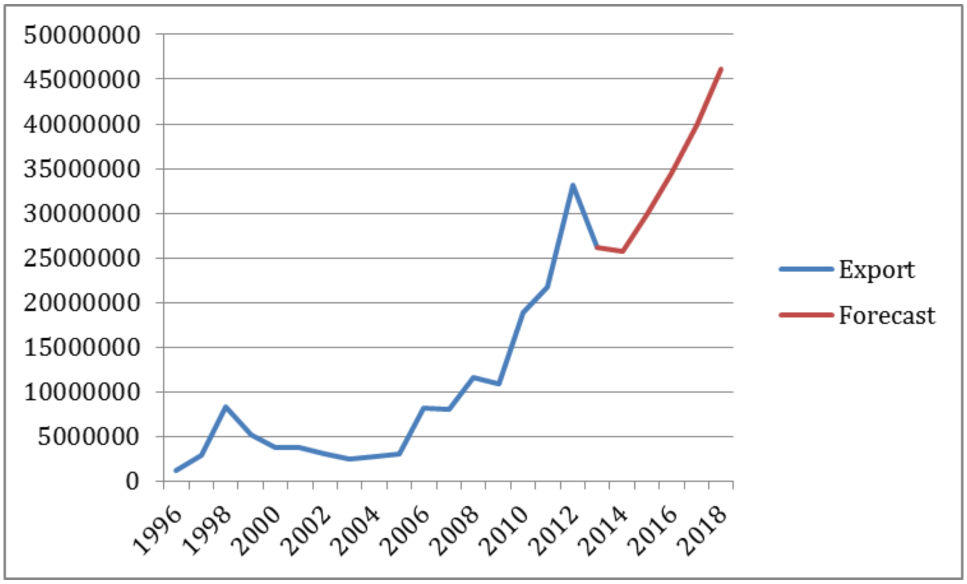

Figure 5-9: Time series plot of exponential growth trend model for export data with forecasts.

5.1.6 Export Model Comparison

In order to select the best model for export, accuracy and error are the two criteria that will be used from both models for this analysis.

Table 5-15 shows the parameters of two models:

Table 5-15: Accuracy measure comparison for export models.

Accuracy Measures	Double exponential method	Exponential growth trend
MAPE	5.73322E+01	4.23184E+01
MAD	3.36168E+06	2.93126E+06
MSD	1.74456E+13	1.86325E+13

In this table, it is observed that the MAPE and MAD measures in the exponential growth trend model are lower than that of the double exponential method, and the MSD criterion is slightly higher, though very close to the number found with the double exponential method.

The following table shows the error of the models for each year:

Table 5-16: Error measurement comparison for export models.

Year	Export	RESI Double Exponential Method	RESI Exponential Growth Trend
1996	1252613	3474961	-634233
1997	2953851	766940.4	772035
1998	8391083	3912246	5868184
1999	5190975	-4346416	2273672
2000	3730299	-3980546	356934
2001	3720131	-2202109	-180592
2002	3067220	-2348230	-1443302
2003	2420320	-2221156	-2795331
2004	2729094	-1097914	-3301919
2005	3039672	-801195	-3934169
2006	8240493	4199669	176433
2007	8027278	-482973	-1297436
2008	11661345	2458690	878900
2009	10895071	-1510674	-1572992
2010	18864607	6527946	4447414
2011	21727549	2611288	5056518
2012	33168575	10238918	13891364
2013	26172077	-7328371	3881262

Figure 5-10 shows that the residuals of the two models have random patterns; therefore, both of models are generally appropriate for the export series. However, based on all the results, it can be concluded that the exponential growth trend model is a more appropriate model for the export data series due to slightly lower MAPE and MAD measurements indicating a higher level of accuracy.

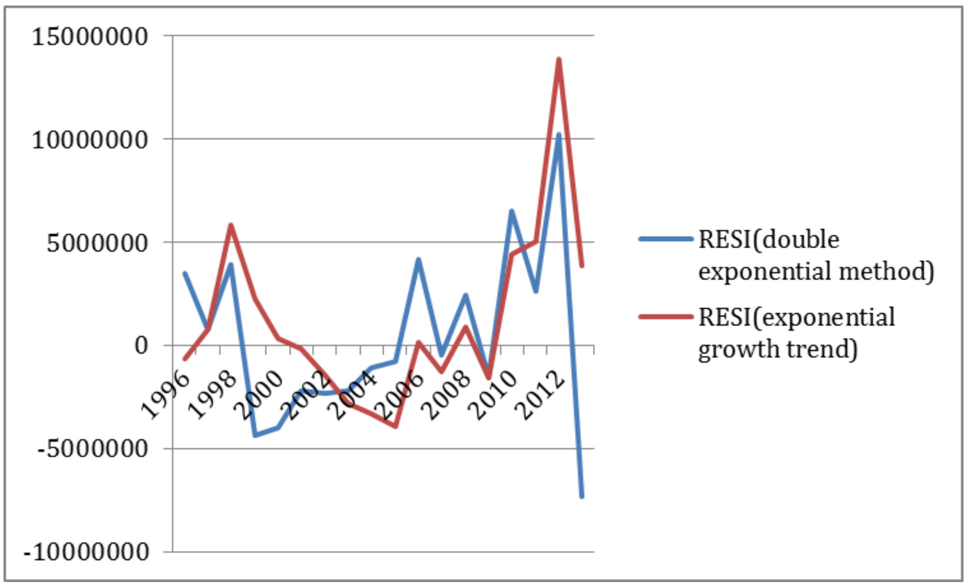

Figure 5-10: Residual series of double exponential method and exponential growth trend model for export data.

5.2 Discussion and Recommendation

5.2.1 E-waste Database

By observing and analyzing the data from UN Comtrade HS code 854810 in this study, one important issue that can be addressed and highlighted that should be placed at the top of other aspects of this field of study for Canada and the other involved countries is the lack of an appropriate e-waste database or even a proper sampled e-waste database in the data world for tracing and monitoring this environmental issue.

As this issue has been mentioned and discussed in other studies quite frequently, a few of these key recommendations from this study prospective are going to be addressed.

By considering the fact that the e-waste category consists of a large portion of used electronic items, establishing a database that can include all these e-waste categories would be a very difficult state to attain at this initial stage. Therefore, having a sample database can be an appropriate solution.

The primary step for establishing such a database can be started by classifying the electronic products into the industrialized items and residential used items category. As the residential electronics that are used in society include the majority of e-waste products, the focus can be on this section.

Additionally, by considering the fact that this segment of electronics consists of a large portion of electronic products, this category needs to be broken down to a smaller one, the specific used electronic items that are used most frequently and consist of a larger quantity of usage in society. There are vast varieties of electronic items in this category whose annual production capacity as well as import and export data in Canada and most of the countries are available.

For this segmentation, Miller et al. [116] suggest seven major electronic items, which include flat screen displays, CRTs, mobile phones, desktop and laptop computers, printers, and circuit boards (both whole and shredded) which come from those products or other electronics [116]. Tracking the last item (circuit boards) is not easy due to the nature of usage in a variety of electronic products. Therefore, this section is not recommended in this study but the rest of the six mentioned electronic products are traceable and therefore are more appropriate for such a database.

In the second step, the data collection strategies for these six major categories need to be addressed. This step can be implemented in two ways; direct or indirect.

In the direct data collection strategy, the data are going to be collected that are directly used as electronics or are e-waste. The most possible way for such data collection to occur has been mentioned in the chart below; through the use of official and unofficial data collection sources.

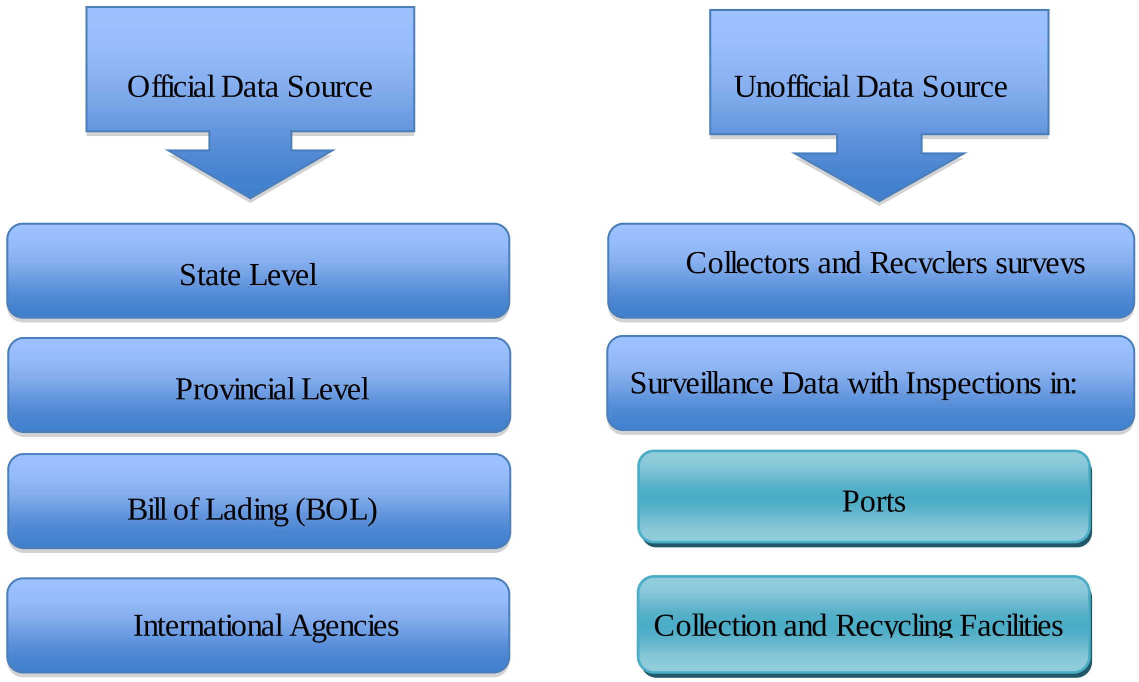

Figure 5-11: Official and unofficial data collection sources.

In the indirect method, the annual production capacity as well as the import and export data of the six sampled categories of electronic products in a specific year is going to be targeted. By comparing this to their optimum usage life cycle, the annual production of these e-wastes can be estimated.

In the final stage, the direct and indirect methods results need to be compared and, generally speaking, the establishment of such a sampled database can help to evaluate more accurately the whole picture of global e-waste including Canada.

5.2.2 Identified Solutions

After having shown the relevant information regarding the past, present and the future situation of the electronic waste in Canada, this section goes through some of the potential solutions for confronting this issue at the national level. There have been several ways that have been identified for controlling the e-waste problem. Green IT might be the most effective solution to this issue which came into discussion after the usage expansion of the electronic products in the past few decades and after the change of global regulations in different countries for confronting this issue. The environmental policy changes are aimed at direct manufacturers of the electronic products in order to move toward a greater usage of the recyclable and less harmful chemical materials in their production lines.

These days by improving the technology and innovation, there are more possibilities that will become evident for decreasing the hazardous effect of the electronic products by their producers [117]. In this way, awareness initiatives with the involvement of the government could be an effective way for designing electronic products that work more efficiently in an environmentally friendly way [48]. The new designs and technologies, such as the Electronic Product Environmental Assessment Tool (EPEAT) or EnergyStar, are examples of those that move toward compatibility with the global environmental green rating systems and standards.

The sales of the registered products by the EPEAT rating system is expected to increase twofold globally in 2010. In that same year, this number increased by nearly a third to more than 4.2 million products in Canada alone [118]. It should be noted that, smaller sizes and lower weights with respect to the volume of the electronic products are being favored. One of the best examples could be the change of design from the cathode ray tubes (CRTs) displays to flat panel displays which are 82% lighter and take 75% lower volume [119].

Furthermore from a technological perspective, the new online data platforms are the other revolution for usage reduction of electronic products and e-waste production. Technologies, such as the effective platform for providing virtual space for documents and programs through the web, also known as cloud computing, enables a variety of users to have unlimited access anywhere in the world without a need for the use of digital products. It is one of the contributing factors that has effectively lowered the weight and size of electronics for both professional and personal use [120]. It has been noted that cloud computing has the potential and capability to lower the carbon emissions by 30% to 90% in organizational platforms [121].

The other revolution from a technological perspective is the expansion of applications from different electronic devices such as smartphones, tablets and smart televisions, which has widely reduced the need of using different devices for different purposes. It is expected that this industry will vastly expand in the future, based on projections that the number of downloads for all apps will hit 187 billion by 2017 knowing that there were 87.8 billion downloads done in 2013 [122], and that there were only 10.9 billion in 2010 [123].

The other effective and controversial solution is having more user involvement in the process of recycling by creating more public awareness for highlighting the role of each individual for decreasing the hazardous effects of used electronic products. By increasing awareness for recycling the old mobile phones among the public as an example, 240,000 tonnes of the raw material emissions can potentially be reduced in the world scale. It is estimated that the total number of mobile phone owners has surpassed 3 billion around the globe, out of which based on the Nokia research, it is estimated that only 3% recycle their phones [28].

The development of national and international legislations in exporter and importer countries is the other possible way for this reduction to occur. As long as these regulations enforce more harmonization among nations, they can be implemented as well as be more influential. On the other hand, more efficient e-waste management through improving different aspects such as technology and safe transportation among developed counties is the other way for ensuring that a reduction occurs [48].

Finally, the most important aspect that needs to be addressed is the importance of expanding the recycling sites and the national recycling capacity due to the reason that the collection and the recycling of the e-waste products can be a potential cause of economic gain for the nation. This can become a potential outcome by considering the fact that most of these products contain the valuable substances that can be recycled and be used again in the new electronic devices As it is estimated, the global electronics end-of-life products offer 40 million tonnes of potential material resources annually, many of which could be reused again towards new useful products [18, 124].

Therefore, the promotion of private businesses to become more involved in this business opportunity could be a bilateral profitable agreement as well, since it serves as a political gain while also being profitable for the private sector. Canada in this sector is more governmental, as in most of the provinces, the non-profit entities are responsible for managing the different programs such as product stewardship programs [48]. The government can act as a more cost effective means if it gives more responsibilities to the private businesses and take the monitoring responsibility in a broader aspect for controlling these activities.

CONCLUSION

The role of the electronic waste as the member of the hazardous waste family in the environment and its trade flow as well as its reason for existence has been vastly discussed for different countries in the academic and non-academic realms. This study has taken a more specific look at this issue on the Canadian scale with the aim of identifying its trade network and its international trade factors, including domestic and international regulations along with reasons of such trades as well as benefits and potential gaps.

The analysis of this study on the UN Comtrade code 854810 as the only available sample database found by the author for tracking the e-waste on the global databases platforms shows that Canada, despite the assumption regarding its export of e-waste toward developing countries as a net exporter of this hazardous waste, is in contrast to this assumption as observations on data have been found to be in the opposite direction.

This research is not a representation of all e-waste flow in Canada due to its data limitations; since the database used is limited to only the waste and scrap of primary cells, primary batteries and electrical accumulators, it therefore does not include all other e-waste categories. Despite the fact that there is no database category defined or existent as electronic waste, this is the only database that exists with its specific characterization for tracking the e-waste directions from 1996 to 2013.

Therefore, the study answered its research question by use of the mentioned database and its conditions as a proxy data by mapping Canada's e-waste trade flows and showing its trends in past years. As the results show, Canada's e-waste flow nature in the last decade has changed from a net exporter to a net importer; therefore, the analysis rejected the initial hypothesis.

There have been several reasons mentioned in this study for explaining the existence of such a trade. The most important ones are as follows: profitability, e-waste transboundry regulations at the international level and international treaties such as the Basel convention that have banned the export of such hazardous waste between countries, especially toward developing ones. This can also be a potential reason that turns this flow towards developed countries, especially those with vastly unpopulated lands such as Canada.

Technology advancements in recent years can also be another contributing factor. Furthermore, a limited amount of mandatory domestic regulations for collecting and recycling the batteries in addition to an excess of domestic recycling capacity for specific sorts of batteries, especially in 2007, might also be another contributing factor.

Lastly, the pollution haven hypothesis effects have been vastly seen over the e-waste trades especially in 2008 to 2012, the years of import expansion. Canada's environmental performance index (CPI) downgraded and the domestic health and environment protection laws strengthened in this time period for Canada's main trade partner countries, such as the United States. This tightness in the environmental regulation as Kellenberg mentioned earlier resulted in an increased export in movements from a country with high environmental regulations to lower ones, resulting in an international waste haven effect.

It should be also noted that, all of the mentioned reasons need to be investigated more in depth with evidence to be proven, as at the moment they are just rational assumptions.

Furthermore, the analysis of the two time series models show the trend of this flow for the next 5 years and the results reveal a brighter picture of what is expected to happen.

Based on this analysis, it can be expected that the import and export growth trends are both rising for the next five years, though the slope of the export growth is more likely to be flat for the first year of these forecasts until 2014.

For the last four years of the estimations, it is expected that the import and the export will both continue rising at almost the same speed. By the end of this period, Canada will still stay similar to the latest stage in 2013 as a net importer of the electronic waste with three times the amount of import than export.

Based on the forecasts and by considering the expansion of the e-waste production in the coming years, this study concludes that it can be a major concern for the environment and the nature of Canada to be a net importer of such a hazardous waste in the future; therefore, it is essential that this topic be further investigated to answer the remaining questions, as this can aid in the betterment of the economy and the environment.

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APPENDIX A - WASTE BY HS CODE

Table A-1: [Waste by HS code] © Elsevier, Inc., 2012. Reproduced with permission [25, table. A1].

hscode	Commodity Description	hscode	Commodity Description
251720	Macadam of slag/dross/sim. industrial waste	520210	Yarn waste (incl. thread waste), of cotton
252530	Mica waste	520299	Cotton waste other than yarn waste
261900	Slag, dross (excl. granulated slag), scalings & oth. waste from mfr.	550510	Waste (incl. noils, yarn waste & garnetted stock) of synth. fibres
262110	Ash & residues from the incineration of municipal waste	550520	Waste (incl. noils, yarn waste & garnetted stock) of art. fibres
271091	Waste oils cont. polychlorinated biphenyls (PCBs)	711291	Waste & scrap of gold, incl. metal clad with gold
271099	Waste oils other than those cont. polychlorinated biphenyls (PCBs)	711299	Waste & scrap of precious metal/metal clad with precious metal
300680	Waste pharmaceuticals	720410	Waste & scrap of cast iron
382510	Municipal waste	720421	Waste & scrap of stainless steel
382530	Clinical waste	720429	Waste & scrap of alloy steel other than stainless steel
382541	Halogenated waste organic solvents	720430	Waste & scrap of tinned iron/steel
382549	Waste organic solvents other than halogenated waste organic solvents	720441	Ferrous turnings, shavings, chips, milling waste, sawdust, filings
382550	Wastes of metal pickling liquors, hydraulic fluids, brake fluids, etc.	720449	Ferrous waste & scrap (excl. of 7204.10-7204.41)
382561	Wastes from chem./allied industries, mainly cont. organic constituents	740400	Copper waste & scrap
382569	Wastes from chem./allied industries, n.e.s. in Ch.38	750300	Nickel waste & scrap
382590	Residual prods. of the chem./allied industries, n.e.s. in Ch.38	760200	Aluminium waste & scrap
391510	Waste, parings & scrap, of polymers of ethylene	780200	Lead waste & scrap
391520	Waste, parings & scrap, of polymers of styrene	790200	Zinc waste & scrap
391530	Waste, parings & scrap, of polymers of vinyl chloride	800200	Tin waste & scrap
391590	Waste, parings & scrap, of plastics n.e.s. in 39.15	810197	Tungsten (wolfram) waste & scrap
400400	Waste, parings & scrap, of rubber (excl. hard rubber)	810297	Molybdenum waste & scrap
411520	Parings & oth. waste of leather/composition leather, not suit. for mfr.	810330	Tantalum waste & scrap
440130	Sawdust & wood waste & scrap	810420	Magnesium waste & scrap
450190	Waste cork; crushed/granulated/ground cork	810530	Cobalt waste & scrap
470710	Recovered (waste & scrap) unbleached kraft paper/paperboard	810600	Bismuth & arts. thereof , incl. waste & scrap
470720	Recovered (waste & scrap) paper/paperboard mainly of bleached chem.	810730	Cadmium waste & scrap
470730	Recovered (waste & scrap) paper/paperboard made mainly of mech. Pulp	810830	Titanium waste & scrap
470790	Recovered (waste & scrap) paper/paperboard (excl. of 4707.10-4707.30)	810930	Zirconium waste & scrap
500310	Silk waste (incl. cocoons unsuit. for reeling, yarn waste & garnetted stock)	811020	Antimony waste & scrap
500390	Silk waste (incl. cocoons unsuit. for reeling, yarn waste & garnetted stock)	811213	Beryllium waste & scrap
510320	Waste of wool/of fine animal hair, incl. yarn waste	811222	Chromium waste & scrap
510330	Waste of coarse animal hair	854810	Waste & scrap of primary cells, primary batteries

APPENDIX B - US EXPORTS OF SLABS TO CANADA, MEXICO AND ALL OTHER DESTINATIONS, 2002-2011

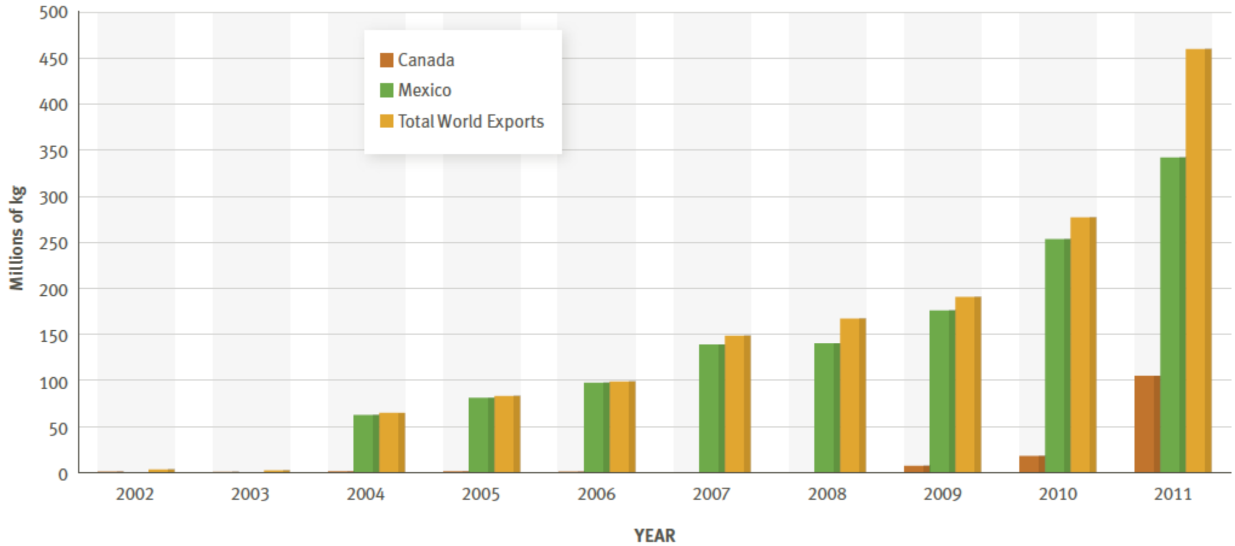


Figure B-1: [US Exports of SLABs to Canada, Mexico and all other destinations, 2002–2011] © Commission for Environmental Cooperation (CEC), 2013. Reproduced with permission [108, fig. 3-1].

APPENDIX C - NORTH AMERICAN IMPORTS AND EXPORTS OF SPENT LEAD-ACID BATTERIES (SLABS), 2011

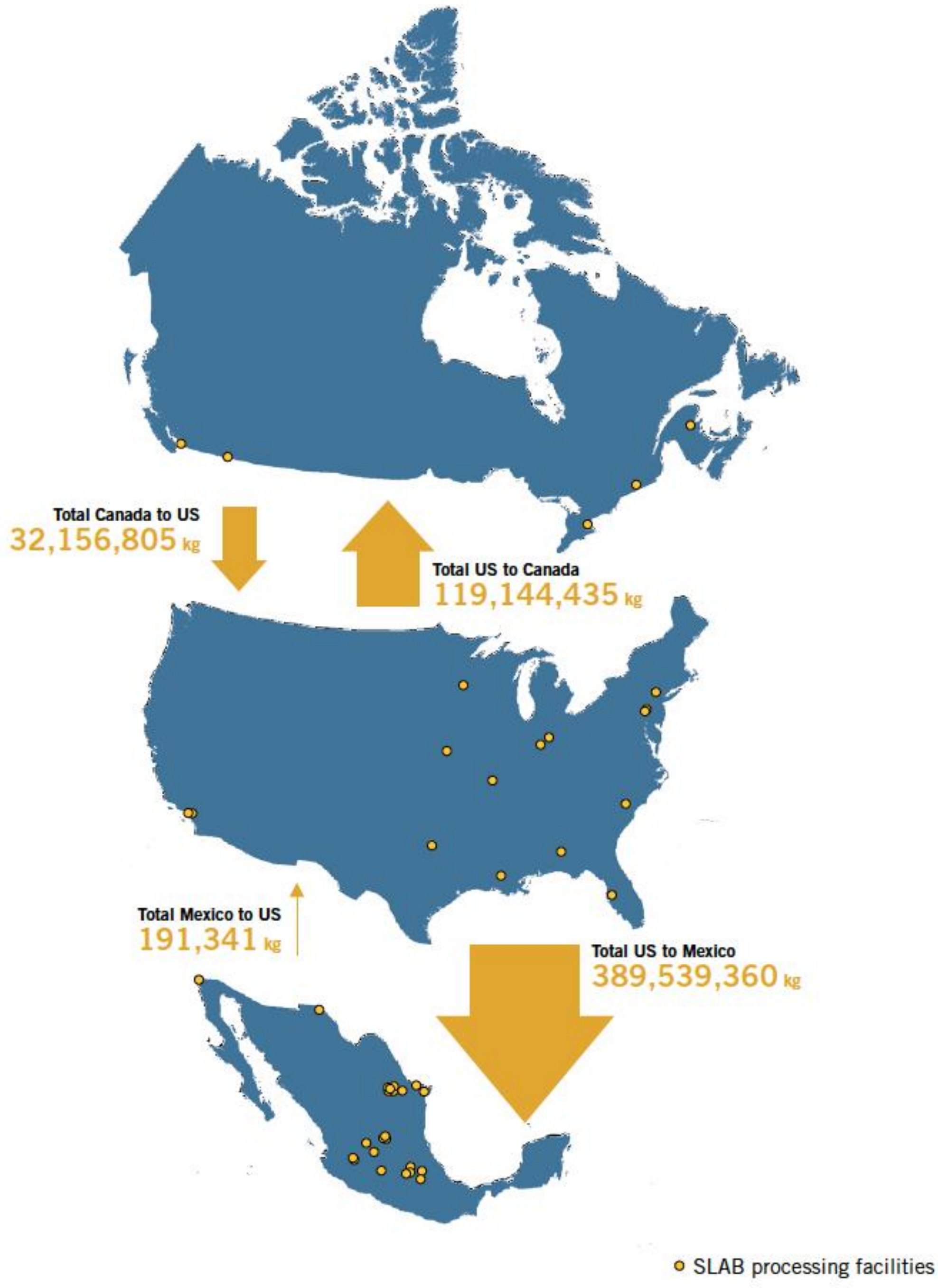


Figure C-1: [North American imports and exports of Spent Lead-acid Batteries (SLABs), 2011] © Commission for Environmental Cooperation (CEC), 2013. Reproduced with permission [108, fig. 3-1].

APPENDIX D - SPECIALTIES AND CAPACITIES OF CONSUMER BATTERY RECYCLING FACILITIES

Table D-1: [Specialties and capacities of consumer battery recycling facilities] © Environment Canada, 2013. Reproduced with permission [109, table. ES-2].

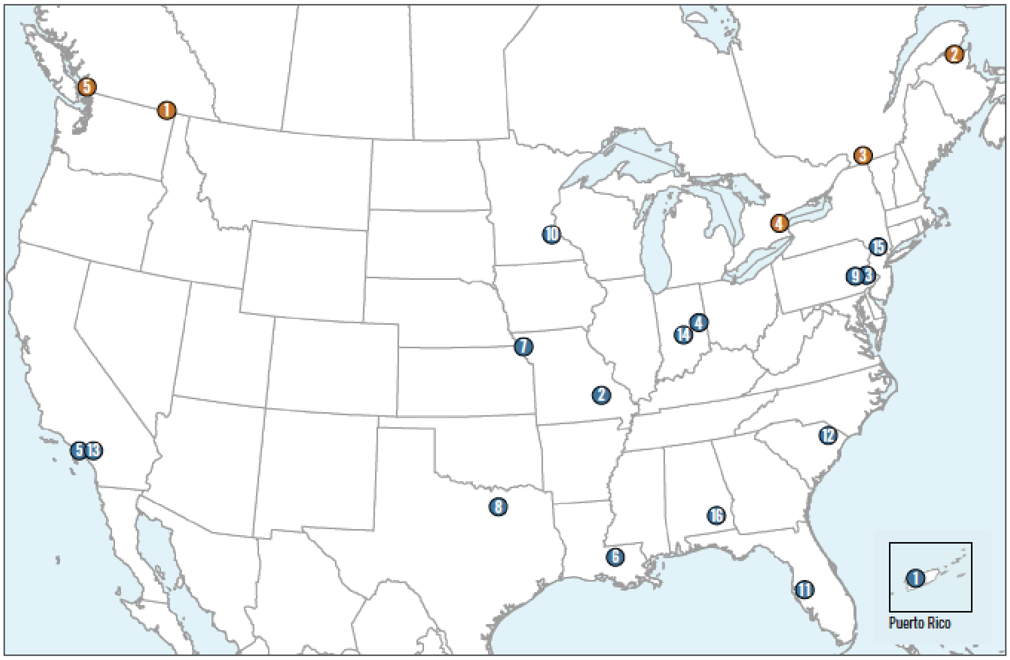
Company	Specialty	Capacity (tonnes/year)	Batteries Reaching End of Life in Canada (2007), tonnes
Toxco, Trail, BC	Lithium batteries, all chemistries	4,500	47 lithium ion + 4 lithium polymer + 333 lithium primary
Teck, Trail, BC	Alkaline batteries in zinc smelter	750	9,734 alkaline
RMC, Port Colborne, Ontario	Alkaline and zinc carbon	70,000	9,734 alkaline
Xstrata, Sudbury, Ontario	Cobalt bearing batteries	6,000 to 7,000	274 NiMH + 47 lithium ion
INMETCO, Pennsylvania	Nickel bearing batteries	6,000	274 NiMH
Toxco, Ohio (Kinsbursky Bros)	Cadmium batteries	15,600 to 19,200	1,915 NiCd

APPENDIX E - CAPACITY OF CANADIAN SECONDARY LEAD SMELTERS

Table E-1: [Capacity of Canadian secondary lead smelters] © Environment Canada, 2013. Reproduced with permission [109, table. ES-3]

Company	Capacity (tonnes/year lead)	Lead from Lead Acid Batteries, tonnes
Teck, Trail, BC	95,000	30,000
Tonolli, Mississauga, ON	45,000	45,000
Newalta, Montreal, PQ	100,000	95,000
Xstrata, Belledune, NB	105,000	10,500
Metalex, BC	4,500	4,500
TOTAL	349,500	185,000

APPENDIX F - FACILITIES PROCESSING SPENT LEAD-ACID BATTERIES (SLABS) IN CANADA AND THE UNITED STATES



Canada

1	Teck Trail Operations	Trail, British Columbia
2	Xstrata Zinc - Brunswick	Belledune, New Brunswick
3	Newalta	Ste-Catherine, Quebec
4	Tonolli	Mississauga, Ontario
5	Metalex Products Ltd.	Richmond, British Columbia

United States

1	The Battery Recycling Company	Arecibo, Puerto Rico
2	Buick Resource Recycling (Doe Run)	Boss, Missouri
3	East Penn Manufacturing Co., Inc.	Lyon Station, Pennsylvania
4	Exide Technologies Inc. - Facility 1	Muncie, Indiana
5	Exide Technologies Inc. - Facility 2	Vernon, California
6	Exide Technologies Inc. - Facility 4	Baton Rouge, Louisiana
7	Exide Technologies Inc. - Facility 5	Canon Hollow, Missouri
8	Exide Technologies Inc. - Facility 6	Frisco, Texas
9	Exide Technologies Inc. - Facility 7	Reading, Pennsylvania
10	Gopher Resource	Eagan, Minnesota
11	Gopher Resource - Envirofocus Technologies	Tampa, Florida
12	Johnson Controls Inc.	Florence, South Carolina
13	RSR Corporation, Quemetco Facility 1	City of Industry, California
14	RSR Corporation, Quemetco Facility 2	Indianapolis, Indiana
15	RSR (Revere Smelting & Refining Corp.)	Middleton, New York
16	Sanders Lead Company	Troy, Alabama

Figure F-1: [Facilities processing Spent Lead-acid Batteries (SLABs) in Canada and the United States] © Commission for Environmental Cooperation (CEC), 2013. Reproduced with permission [108, fig. 1-1a].

APPENDIX G - THE MAIN TRADE PARTNERS WITH RESPECT TO THE OVERALL NUMBER OF TRADE REPORTED BY CANADA, FROM 1996 TO 2013

Table G-1: [The main trade partners with respect to the overall number of trade reported by Canada, from 1996 to 2013].

Trade Partner	Number of Trades	Category
USA	36	More than 10 number of trades
China	21	
Japan	20	
UK	19	
Mexico	17	
Germany	17	
France	15	
Australia	9	More than 2 number of trades
Italy	8	
Israel	8	
Malaysia	8	
Netherlands	8	
Switzerland	8	
UAE	8	
Singapore	7	
China, Hong Kong SAR	7	

Table G-1: [The main trade partners with respect to the overall number of trade reported by Canada, from 1996 to 2013] (cont'd).

Trade Partner	Number of Trades	Category
Austria	6	More than 2 number of trades
Sweden	6	
Norway	5	
India	5	
South Africa	4	
Ireland	4	
Indonesia	4	
Cuba	4	
Rep. Of Korea	4	
Spain	3	
Viet Nam	3	
Nigeria	3	
Costa Rica	2	1 or 2 number of trades
Haiti	2	
Thailand	2	
Venezuela	2	
Russian Federation	2	
Saint Pierre and Miquelon	2	
Saudi Arabia	2	
Belgium	1	
Bermuda	1	

Table G-1: [The main trade partners with respect to the overall number of trade reported by Canada, from 1996 to 2013] (cont'd and end).

Trade Partner	Number of Trades	Category
Brazil	1	1 or 2 number of trades
Chile	1	
Denmark	1	
Dominican Rep.	1	
Ecuador	1	
El Salvador	1	
Greenland	1	
Madagascar	1	
Mongolia	1	
Montenegro	1	
New Zealand	1	
Panama	1	
Philippines	1	
Poland	1	
Portugal	1	
Swaziland	1	
Syria	1	
Ukraine	1	
United Rep. of Tanzania	1	

APPENDIX H - MAPE DEFINITION AND EQUATION

MAPE: "…Mean Absolute Percentage Error (MAPE) measures the accuracy of fitted time series values. It expresses accuracy as a percentage…" [115].

The MAPE equation is as follows:

$$MAPE = \frac{\sum_{t=1}^{n} |(y_t - \hat{y}_t)/y_t|}{n} \times 100 \quad (y_t \neq 0)$$

"…Where y_t equals the actual value at time t, $\hat{y}_t$ equals the fitted value, and n equals the number of observations…" [115].

APPENDIX I - MAD DEFINITION AND EQUATION

MAD: "…Mean Absolute Deviation (MAD) measures the accuracy of fitted time series values. It expresses accuracy in the same units as the data, which helps conceptualize the amount of error…" [115].

The MAD equation is as follows:

$$MAD = \frac{\sum_{t=1}^{n} |y_t - \hat{y}_t|}{n} \quad (y_t \neq 0)$$

"…Where y_t equals the actual value at time t, $\hat{y}_t$ equals the fitted value, and n equals the number of observations…" [115].

APPENDIX J - MSD DEFINITION AND EQUATION

MSD: "…Mean Squared Deviation (MSD) is always computed using the same denominator, n, regardless of the model. MSD is a more sensitive measure of an unusually large forecast error than MAD…" [115].

The MSD equation is as follows:

$$MSD = \frac{\sum_{t=1}^{n}(y_t - \hat{y}_t)^2}{n} \quad (y_t \neq 0)$$

"…Where y_t equals the actual value at time t, $\hat{y}_t$ equals the forecast value, and n equals the number of observations…" [115].